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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 58.

L. O. HOWARD, Entomologist and Chief of Bureau.

SOME INSECTS INJURIOUS TO FORESTS.

I. THE LOCUST BORER.

By A. D. HOPKINS, *In Charge of Forest Insect Investigations.*

II. THE WESTERN PINE-DESTROYING BARKBEETLE.

By J. L. WEBB, *Special Field Agent, Forest Insect Investigations.*

III. ADDITIONAL DATA ON THE LOCUST BORER.

By A. D. HOPKINS, *In Charge of Forest Insect Investigations.*

IV. THE SOUTHERN PINE SAWYER.

By J. L. WEBB, M. S., *Agent and Expert.*

V. INSECT DEPREDATIONS IN NORTH AMERICAN FORESTS AND PRACTICAL METHODS OF PREVENTION AND CONTROL.

By A. D. HOPKINS, PH. D., *In Charge of Forest Insect Investigations.*

WASHINGTON:

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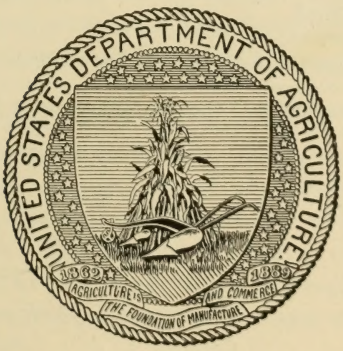

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1910.

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[a] Transferred to another branch of the bureau.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., August 5, 1910.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 58, five papers dealing with insects injurious to forests and forest products. These papers were issued separately during the years 1906 to 1909.

Part I, "The Locust Borer," by A. D. Hopkins, comprises a summary of information from published accounts, supplemented by data secured by recent investigations, and deals more particularly with practical methods for controlling this, our most important enemy of the black locust. It is designed to be of service to owners of plantations and forests, as well as to investigators, in the prevention of injuries to this useful tree.

Part II, "The Western Pine-destroying Barkbeetle," by J. L. Webb, has special reference to the results of investigations by Mr. Webb in central Idaho in 1905, but relates also to the results of other investigations and to available information on the insect and methods of controlling it.

Part III, "Additional Data on the Locust Borer," by A. D. Hopkins, comprises a partial revision of Part I and gives additional information based on the results of investigations carried on since that part was issued.

Part IV, "The Southern Pine Sawyer," by J. L. Webb, gives the results of special investigations by Mr. Webb and relates to a subject of much economic importance to the timber interests of the Southern States, and especially of sections in which the pine timber is damaged by storms. The results of these investigations and the information contained in this paper make it possible to avoid a large percentage of the losses from damage by the sawyer, which have heretofore seemed inevitable.

Part V, "Insect Depredations in North American Forests and Practical Methods of Prevention and Control," by A. D. Hopkins, gives a summary of facts, conclusions, and estimates relating to the forest-insect problem as applied to North American conditions and calls attention to its importance in the future management of private,

state, and national forests. The matter is presented in as brief and concise a form as possible, in order that the information may be readily available to the general reader, as well as to the forester and student, and references are made to publications in which more detailed accounts may be found. The statements and conclusions relating to the insects and their work and to methods for their control are based almost entirely on investigations and observations by Doctor Hopkins and by assistants in the Bureau of Entomology working under his direction, carried on in all of the principal forest areas of the United States.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. W. M. Hays,
Acting Secretary of Agriculture.

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[a] The five papers constituting this bulletin were issued in separate form on June 13 and August 18, 1906; March 5, 1907; and November 10 and December 4, 1909, respectively.

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U. S. D. A., B. E. Bul. 58, Part I. F. I. I., June 13, 1906.

SOME INSECTS INJURIOUS TO FORESTS.

THE LOCUST BORER.

(*Cyllene robiniæ* Forst.)[a]

By A. D. Hopkins,

In Charge of Forest Insect Investigations.

OBJECT OF PAPER.

The object of this paper is to give a summary of the more important published information, supplemented by recently determined new facts relating to the locust borer and methods of controlling it, which will be of service to the investigator in the determination of additional facts, and to the owners of plantations and forests in suggesting methods of preventing losses.

ECONOMIC IMPORTANCE OF THE INSECT.

The economic importance of the well-known locust borer as affecting the growth of the black locust or yellow locust (*Robinia pseudacacia*) is fully realized by everyone who is interested in this valuble forest and shade tree, and the urgent need of additional information on the subject is indicated by the frequent inquiries of correspondents and by the recent articles in newspapers, journals, and special publications which have been called forth by the proposed extensive commercial planting of the locust by railroad and other companies and by individuals.

INVESTIGATIONS.

In connection with the general study of insects injurious to forest trees, the locust borer has received considerable attention by the writer since 1890.[b] In March, 1905, a plan of cooperation between the

[a] Order Coleoptera, Family Cerambycidæ.

[b] From 1890 to 1892 for the West Virginia Experiment Station, and since 1902 for the U. S. Department of Agriculture.

Bureau of Entomology and the Forest Service in the investigation of insect enemies of the black locust was proposed and adopted, by which the subject is receiving special attention from the viewpoint of both the forester and the entomologist, with the primary object of practical results.

CHARACTER OF THE INSECT AND ITS WORK.

The locust borer is a whitish, elongate, so-called "round-headed" grub or larva (fig. 1), which hatches from an egg (fig. 2) deposited by a black or brown and yellow striped long-horned winged beetle (fig. 3) found on the trees and on the flowers of golden-rod from August to October. The eggs are deposited in the crevices of the bark of living, growing trees from August to October, and the young borers (fig. 2, *b*, *c*) hatching therefrom mine into the outer portion of the living inner bark (fig. 5), where they pass the winter, and in the spring bore through the bark into the sapwood and heartwood. Here they transform in July and August to pupæ (fig. 4) and in August and September to adult beetles, which soon emerge from the trees and deposit eggs for the next annual generation of borers and beetles.

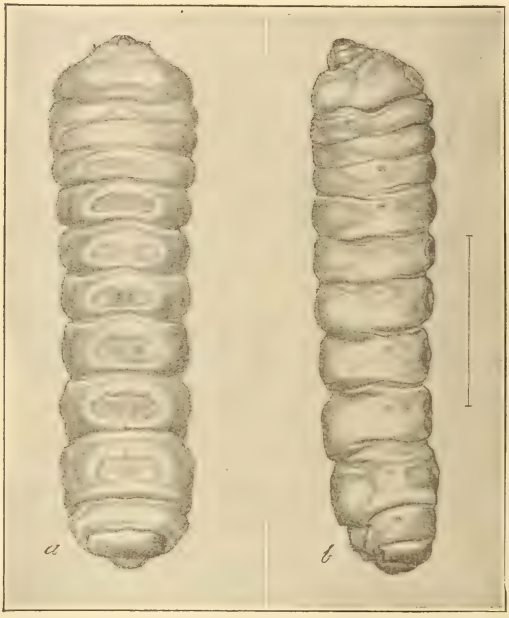
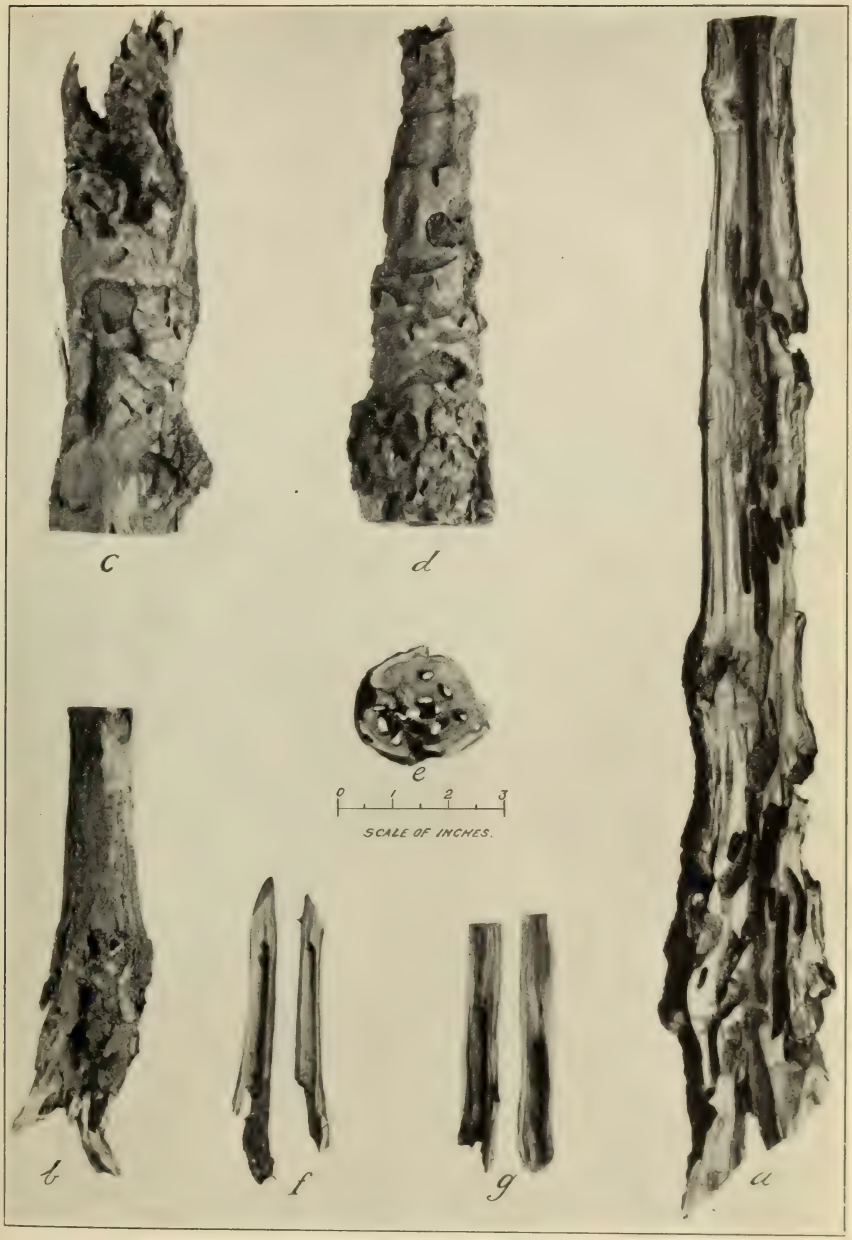


FIG. 1.—The locust borer (*Cyllene robiniæ*): *a*, larva, dorsal view; *b*, same, lateral view. Line at right represents natural length (original). The larva in profile should show minute prothoracic feet.

The injury to the trees (Pl. I) consists of wounds in the bark and sapwood which, if sufficiently severe or repeated year after year, result in either a stunted worthless growth or the death of young and old trees, while the numerous worm holes in the wood reduce its commercial value or render it worthless.

The presence of the insect in injurious numbers is indicated (1) by the frequency of the adults on the golden-rod flowers and on the trees, from August to October; (2) by the slight flow of sap and by the brownish borings where the young larvæ are at work in the bark, during April and May; (3) by the whitish sawdust borings lodged in



WORK OF THE LOCUST BORER.

a, Section of young tree 3 inches in diameter; *b*, section of young tree 2 inches in diameter, which was broken off near surface of ground; *c*, *d*, section of branch from badly damaged tree, showing healing wounds in surface of wood; *e*, transverse section of same; *f*, *g*, sections of branches one-half inch in diameter or less, showing in each the total length of burrow in which a larva developed and transformed to the adult beetle. (Original.)

the rough bark, in the forks of the tree, and on the ground around the base of the trunk, during May, June, and July; (4) by the breaking down of the branches and young trees, and by the sickly appearance of the young twigs and leaves in July and August.

This insect appears to be present and more or less injurious in all of that part of the United States which is east of the Great Plains and north of the Gulf States. Published information and reports of forest officials and others indicate that in Oklahoma and Indian Territory and west of the Great Plains the locust is now quite free from injury by the borer; but that these regions will remain exempt is by no means certain.

EXTENT OF DAMAGE OR LOSS.

So extensive is the damage to natural growth, artificial plantations, and shade trees that in some sections within the natural range of the tree in the Eastern States, but particularly in the Middle West, where both the tree and the insect have been introduced, it is considered unprofitable to grow the tree for shade or timber, and in such sections the natural sprout growth is often considered a pest rather than otherwise.

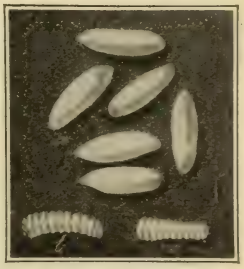


FIG. 2.—The locust borer (*Cyllene robiniæ*): *a*, eggs; *b*, *c*, larvæ from hibernation cells. Much enlarged (original).

The loss resulting from defective timber, stunted growth, and the death of trees is represented by the difference in value between the damaged growth or product and the same if uninjured and healthy. This, if expressed in dollars, would represent a large sum.

POSSIBILITIES OF PREVENTING LOSSES.

There are sections, especially in the natural home of the tree, where, as has been frequently observed by the writer and others, the damage is not sufficiently severe to seriously affect the vitality of the trees or the commercial value of the product; and our present knowledge of the insect and of methods of preventing losses from its ravages indicates that in properly selected localities, and under proper forestry methods of management, the tree, so far as this insect is concerned, can be grown successfully on an extensive scale, and can be made to yield most satisfactory returns.

HISTORICAL REFERENCES.

The first reference to this insect, according to Fitch, is a figure and description by Pitiver in his Gozophylacium, published in London in 1702. Drury figured it in 1770, and the following year, 1771, Forster gave it the specific name of *robiniæ*, under which it is at present rec-

ognized. It has been referred to many different genera, but is now recognized as belonging to the genus Cyllene. Both Drury and Forster received it from the "Province of New York," and referred to it as inhabiting the locust tree (*Robinia pseudacacia*). It is therefore evidently an American species.

Some of the principal writers who have contributed important facts on the life history, habits, distribution, and remedies are: Dearborn, 1821; Harris, 1826–1841; Fitch, 1858–1863; Walsh, 1865–1867; Riley, 1867; Lintner, 1890; Schwarz, 1890; the writer, 1891–1898; Felt, 1901–1905; Cotton, 1905; White, 1906, and others. (See list of publications, p. 15.)

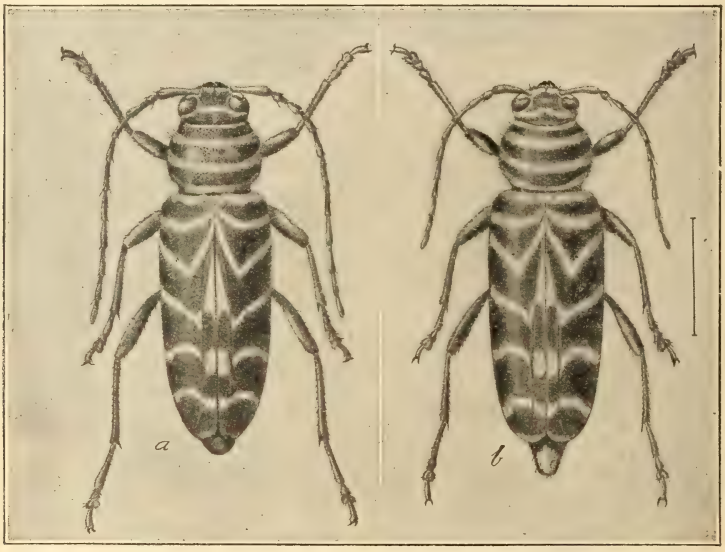


FIG. 3.—The locust borer (*Cyllene robiniæ*): *a*, male beetle; *b*, female beetle. Much enlarged (original).

REVIEW OF PUBLISHED DATA.

Gen. H. A. S. Dearborn was the first to record the more important facts in the life history and habits of the insect. Indeed, so complete and accurate were his observations that comparatively little has been added by subsequent writers, who have extensively quoted and repeated them. He found the beetles on the trunks of trees from the 1st to the 25th of September, the females depositing their "snow white" eggs in the crevices of the bark, four to nine in each place. These eggs hatched before cold weather, and "the young larvæ just buried themselves in the tender inner bark," where they remained until about the 1st of April, when they commenced boring, and soon passed into the solid wood. He stated that it could always be ascertained when and where the borers were at work by the oozing of sap from the wounds

made by them. By the 20th of July the larvæ attained their full size, by the 28th some of them changed to pupæ, and the perfect insects were on the trees September 3. These observations were made on his grounds near Roxbury, Mass., during several years previous to 1821, when they were reported in a letter to John Lowell, and published, together with an account of his unsuccessful experiments with whitewash, mortar, and plaster, in the Massachusetts Agricultural Journal, Volume VI, 1821, pages 270–275.

Col. T. Pickering, in a letter to Mr. Lowell the same year and published in the same volume, stated that there were trees in New Hampshire uninjured by the borer, as well as in some of the Southern States; that he had observed the stems of young trees in Washington, D. C., infested, while in Georgetown (D.C.) he saw large thrifty trees uninjured; and he concluded that natural growth in groves was much less liable to injury than transplanted growth.

Fitch, writing in 1858, stated that numbers of specimens were sent to him year after year from Indian Territory.

FIG. 4.—The locust borer (*Cyllene robiniæ*): *a*, pupa, ventral view; *b*, same, dorsal view. Much enlarged (original).

Schwarz (1890) observed that in and around the District of Columbia the insect lives in large colonies, affecting all trees of small groves, while long hillsides full of locust are not infested.

R. S. Kellogg, in his discussion of forest planting in western Kansas, says:[a]

> By locating plantation on good ground and giving it first-class care, the trees will reach fence-post size before the borers do much damage. They should then be cut and utilized. The rapid sprout growth will soon make a new crop. A stump sprout sometimes attains a height of 10 feet the first season. Handled in this manner, black locust can be profitably raised in many places where it is altogether unsuited for a permanent tree.
>
> At present borers are a menace to black locust trees throughout western Kansas and Nebraska, though there are occasional local areas that are not affected. They

[a] Bul. 52, Bur. Forestry, U. S. Dept. Agric., 1904.

have so far done little damage in southwestern Kansas, but they are moving both southward and westward. They are abundant at Pratt, Kinsley, Dodge, and Scott, and are appearing at Medicine Lodge, Coldwater, Meade, and Garden City. Yet of the numberless trees that have been killed or seriously injured nearly all reached a size that could well be used for posts or stakes before succumbing. This shows that black locust may be successfully grown in commercial plantations if cut as soon as large enough for posts. * * *

Just south of the Kansas line, in Woods County, Okla., black locust grows remarkably well, and has not yet been molested by borers.

Cotton (1905) observed that in Ohio injury was greater in single trees and plantations of considerable size than in natural forests.

Dearborn found that whitewashing the trees in April and filling the holes with mortar in July was not entirely successful as a remedial measure, but he suggested cutting out and burning infested trees in April and protecting the young, thrifty trees. Harris suggested the collection of the beetles by children, and Fitch, the planting of goldenrod to attract the beetles, so that these could be collected and destroyed. Lintner suggested the application of soap solution and carbolic acid to prevent the beetles from depositing eggs, and the cutting out of young larvæ when their presence is indicated by sap and borings. Riley suggested destroying the young borers as soon as hatched. The writer recommended severe pruning in March, and clean culture was recommended by Felt.

The insect has been recorded from Canada southward to Pontchartrain, La., Texas, and Indian Territory, and westward into Nebraska.

Some of the records of destructive ravages are the following: Peck (1818), Harris (1826), in New England; Fitch (1858), in New York; Rogers, Reed, and Bethune (1855 to 1867), in Canada; Walsh (1866), in Illinois and Kansas; Laurent (1893), around Philadelphia; the writer (1891 to 1898), in West Virginia; Smith (1898), in New Jersey; Cotton (1905), in Ohio; White (1906), in the Mississippi Valley, about twenty years after extensive planting was begun by settlers.

REVISION OF PUBLISHED DATA.

Some of the published records relating to the insect which have been frequently quoted or repeated require, according to the writer's observations, some amendments and corrections.

It would appear that normally but a single egg is deposited in a place, rather than clusters of four to nine. The female does not pierce the bark or place her eggs in the cambium layer. The larvæ do not enter the sapwood before winter, but, as observed by Dearborn and verified by the writer, remain in the outer portion of the inner bark. Records of the insect infesting honey locust are probably due to the fact that the black locust is sometimes referred to under this name, which is the correct one for an entirely different tree. It

appears now that its attack is confined entirely to Robinia. It is not necessary that a tree or branch should be some inches in diameter before it is damaged, for the writer has found full-grown larvæ in sprouts and branches less than one-half inch in diameter.

In the writer's opinion, all attempts to cultivate locust in the eastern United States *should not be abandoned* on account of the borer, although this has been recommended by some recent writers. It has been stated that the locust would probably not be injured by the borer in the southern limit of its range and in the country west of the Great Plains. While this may be true, precaution should be taken to prevent its introduction into such localities, since it is not improbable that if the insect be introduced and become established it may prove even more destructive there than in its natural home, as was demonstrated in the Mississippi Valley.

Nearly all methods heretofore recommended are subject to practical application to shade trees and small plantations only; therefore there is special need for suggestions of practical methods of combating the insect and preventing losses in large commercial plantations and in natural forest growth, and it is hoped that this paper will contribute something of value along this line.

OBSERVATIONS BY THE WRITER, 1890–1905.

Adults were collected on golden-rod flowers at Piedmont, Md., and Mineral County, W. Va., on August 25, 1890, and on golden-rod and locust leaves at Morgantown, W. Va., September 16 and 17, 1891. Young larvæ were found mining in living bark of trees at Kanawha Station, W. Va., May 1, 1891, and on May 20 the same larvæ had entered the wood, but a great many had died.

It was frequently noted that the locust in the forests of Chestnut Ridge in Monongalia and Pendleton counties, Laurel Hill in Preston County, and especially on Rich Mountain in Randolph County, W. Va., showed but slight damage by the borers. Similar observations were made in many other sections of the State, while in near-by and widely separated sections the damage was found to have been severe and continuous during the life of some of the older trees. In 1898 it was observed that badly damaged shade trees near Morgantown, W. Va., which had been severely pruned in March and April, had recovered, and the crowns were renewed by dense, vigorous, healthy growth, which suggested this method of treating badly damaged shade trees.

On October 9, 1904, it was found that the locust in the vicinity of Chevy Chase, Md., was but slightly damaged by the borer, although beetles were found in numbers on golden-rod and feeding on sap from wounds in bark of living sumac. This habit of feeding on sap is of special interest from the fact that it suggests the possibility of killing

the beetles by means of a bait of some poisoned substance which would be attractive to them.

On May 23, 1905, it was found that the locust trees of all sizes in the open and in dense thickets along the old canal on Arlington Farm, Virginia, were thickly infested with the borers, which were all in the wood and ranged in size from quite small to nearly full grown. The ground around some of the trees in the open and on the borders of the groves was found to be covered with the sawdust borings to the depth, in some cases, of an inch or more, and the larvæ could be distinctly heard at work in the wood. Some of the young trees had been literally honeycombed and were broken off at the ground, others had many branches broken and hanging by the bark or fallen from the tree, and some other trees had the leaves turning yellow and dying, while one isolated tree in a field had failed to put forth leaves on some of the branches. Some infested branches cut on this date and placed in a box in the laboratory were found on July 12 to contain fully matured adults, and on July 20 they began to emerge, thus showing that the larvæ will complete their development in the wood after it is cut from the tree and becomes perfectly dry. Indeed, this record shows that the dry condition contributes to the rapid development of the insect, for on the same day (July 20) on which the beetles were found in the box, the trees from which the branches had been cut were examined and found to contain nothing but larvæ. Some more branches were cut on this date and placed in a tin can, where they were kept moist. The first beetles emerged from these on August 24, or more than thirty days after adults had emerged from the dry branch. On August 30 many adults had emerged. September 20 ten living adults and many dead ones were taken from the can, and on October 2 several more dead ones were removed.

When the trees were examined on July 20, a larva was found mining in a two-year-old branch less than one-half inch in diameter, and the cocoon of a parasite of the borer was found in one of the mines, but the adult parasite was not reared. Many dead borers were found in their mines in the trunks and branches surrounded by a white powdery fungus.

The trees were again examined on September 14, when adults were found abundant on the foliage, branches, and stems, and also on flowers of golden-rod. Adults and pupæ were also found in considerable numbers in the dead wood of broken branches, as well as in the living wood, and dead larvæ were frequent. Larvæ of an elaterid (click beetle) were quite frequent in the wood, where they had evidently been feeding on the locust borer.

Examination during August, 1905, of the locust on a hill near Kanawha Station, W. Va., where this tree forms the principal growth over old abandoned fields and in the adjacent forests, showed that the

damage by the borer was very slight in trees of all sizes. On August 26 many adults and a very few pupæ, but no larvæ, were found in small trees in the valley, while the large trees in the same locality were but slightly damaged.

OBSERVATIONS BY MEMBERS OF THE FOREST SERVICE.

The following notes by Mr. S. N. Spring, forest assistant in the Forest Service, were submitted October, 1905, as a contribution to the results of cooperative studies. Early in July the work of the borer was noticed in the central portion of Westmoreland County, Pa. The first adult insect was seen on August 29. Evidence of the work of this insect was found in the localities investigated, but, for the most part, it was not serious enough to prevent the planting of locust for fence posts. To the north and west of Greensburg, in Westmoreland County, and in Allegheny County many roadside trees were badly bored. The work of the borer is slight on Chestnut Ridge and Laurel Hill, where locust thrives. Posts and pit props cut in these mountains show slight injury only. In the few places where injury was found to be great, within the area studied, the trees were dying, and many branches were broken off where the trees had been extensively bored by this insect. Owing to the fact that places of serious injury were so few, it was impossible to carry out any observations that would be of value in a study of immunity. In general the locust on the two high ridges thrived better than those on the lower elevation of Westmoreland and Fayette counties, and less injury due to this insect was found among the trees on the ridges.

Mr. J. W. Fetherolf, of the Forest Service, informed the writer, on January 26, 1905, that a grove of black locust planted in Salt Lake City, Utah, prior to 1850, is still in a thrifty condition and apparently free from all insect injury. The same can be said about this species seen elsewhere in the Salt Lake Valley.

Mr. Wesley Bradfield, of the Forest Service, informed the writer that he found the adult beetles common on badly damaged trees, 5 to 8 years old, near Marshall, Mich., in August, 1905; also, that according to his observation the locust in the southern quarter of Michigan was seriously damaged, while in the northern three-quarters, especially toward Lake Michigan, it was not.

RECENT OBSERVATIONS BY THE WRITER.

On March 11, 1906, it was found at Arlington Farm, Virginia, that the young larvæ had passed the winter in minute cells which they had excavated in the outer layers of the living bark and just beneath the outer corky bark (fig. 5), as recorded by Dearborn. So common were these hibernating larvæ in the trees that in the bark of some of them there were fifteen or twenty within an area of a few square inches;

but of the several hundred examined there was only one larva in a place, which would indicate that the eggs are not deposited in clusters, but that they are scattered about in the crevices, so that each larva occupies a separate hibernating cell. The slight wound thus produced in the outer layer of the living bark results in a small dead area surrounding the cell. This dead and brown condition was found, on the date mentioned, to have penetrated the thick inner bark to the wood. This condition evidently facilitates the operation of the young larva in boring through the inner bark to the wood, which a healthy condition of the immediately surrounding bark might prevent. It is not improbable that this small area of dead bark may be caused by a plant disease, which finds its way to the living plant tissue through the slight wound made by the larvæ and which, if this be so, may contribute greatly to the death of badly infested trees.

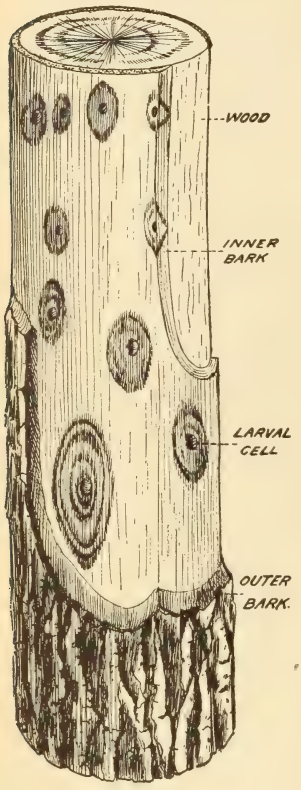


FIG. 5.—The locust borer (*Cyllene robiniæ*): Hibernation or larval cells in outer portion of living inner bark. About natural size (original).

The young larvæ were found in nearly every case in the part of the bark which had not been injured previously, thus indicating that the female deposits her eggs where the bark is perfectly healthy and not in or around the old scars. Indeed, the habit of the larvæ appears to render this quite necessary for their more or less isolated work. It was particularly noted that the remaining unaffected bark of the trees which had suffered most from previous generations of the insect was thickly infested with hibernating larvæ, while that of near-by large trees which had escaped previous injury contained very few, thus indicating that from some cause there are individual trees which are more or less immune. This fact, which has been so often observed, suggests the importance of experiments in the propagation of immune stock by means of seed or root cuttings from immune trees growing among badly infested ones.

The hibernating habits of the larvæ also suggest a simple method of destroying them, namely, the cutting and barking of the trees during the period between the first of November and the first of May. The simple removal of the bark, without burning, is sufficient to kill the larvæ.

It should be remembered that all the holes found in a tree and all other damage by the borer are not the work of one generation, but usually that of repeated annual attack during the life of the tree; also, that a burrow in the sapwood of a young tree remains the same burrow in the heartwood of the old tree, without change, except in the healing of the original entrance; therefore the number of borers and the amount of damage each year is not so great as it might appear, and, while each female is doubtless capable of depositing more than a hundred eggs,[a] it would appear from the writer's observations that only a small percentage of the larvæ hatching from them survive the bark-infesting stage or complete their development to the adult stage. This suggests that any method of management which will insure the destruction of a large number of larvæ and beetles each year will reduce the damage to a point where there will be practically no loss.

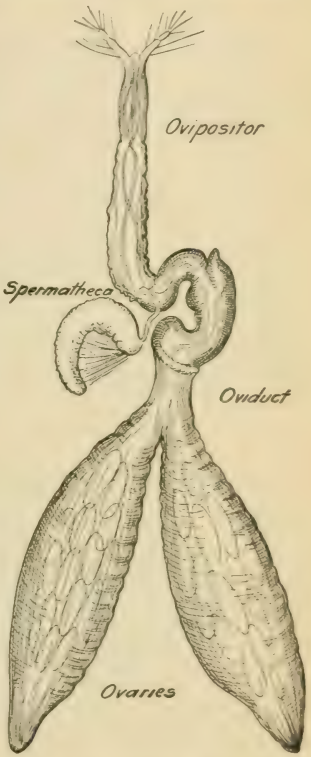


FIG. 6.—The locust borer (*Cyllene robiniæ*): Reproductive organs of female beetle. Highly magnified (original).

SUGGESTIONS FOR CONTROLLING THE INSECT AND PREVENTING LOSSES.

With our present knowledge of the life history and habits of the locust borer, it would appear that the following suggestions might be of practical value in the control of insects in large plantations and forests.

The fact that the young larvæ from eggs deposited during the summer remain in the outer bark during the winter and do not enter the wood until the following May suggests that if locust for all purposes were cut between November and May, the bark removed from that portion which is of value, and the remainder burned, it would destroy vast numbers of the insects and contribute greatly toward the protection of the remaining growth.

The fact that badly infested trees may be detected during May, June, and July by the ejected sap and borings, suggests this simple method of locating such trees, which should be cut close to the ground and burned, before the first of August, to destroy the borers before

[a] An examination of the ovaries (fig. 6) of beetles collected in August shows that they may contain as many as fifty mature eggs at one time, in addition to a large number of immature ones.

they transform to the adult beetles and emerge. If preferable, the same end may be accomplished by burning the tops and worthless parts and by submerging the valuable parts in ponds or streams until the borers are killed.

DAMAGE TO CUT WOOD AND DANGER OF INTRODUCTION INTO NEW LOCALITIES.

As we have shown that after the borers have once entered the wood they may complete their development in the cut and dry branches, they will evidently do so in posts or other material manufactured from trees cut between the first of May and the middle of September; therefore, it is plain that locust should not be cut during this period for any purpose except to destroy the borers, or, if it should be necessary to cut it, the tops should be burned and the logs submerged in ponds or streams for a few days before they are shipped or manufactured. This is very important both to prevent damage to the manufactured material and the introduction of the insect into the far West and other sections of the country which are at present free from it.

PROPER LOCATIONS FOR EXTENSIVE PLANTATIONS.

The fact that there are many sections and localities of greater or less extent within the natural home of the locust and its insect enemies where, from some unknown cause, the tree grows to large size and old age without perceptible injury from borers and other insects, suggests the importance of selecting such localities for any proposed extensive operations in the line of artificial plantation, or utilization of natural growth. It will be found, however, that no area of considerable extent, even in such localities, is entirely free from this and other destructive insect enemies, and that certain precautions and well-planned methods of management with reference to their control will be necessary.

PRELIMINARY REQUISITES.

In the first place it is necessary, in order to provide against future losses from the borer, that a thorough survey be made in May and June, not only of the area to be utilized but of the entire neighborhood for a radius of a mile or more from its borders, for the purpose of locating and destroying scattering trees and groves which are more or less seriously infested or damaged by the borer. It would seem that the control of such large areas, by purchase or under a plan of cooperation between the owners of the land or trees, is one of the most important requisites for success in preventing future losses from the ravages of this and other insects in small as well as large plantations.

In fact, it is the writer's opinion that, with this precaution properly and continuously carried out, locust may be successfully protected from the borer in any locality.

SUBSEQUENT MANAGEMENT.

In the subsequent management of plantations and of natural forest and sprout growth it is important each year to locate and destroy the worst infested trees for the purpose of killing the borers in the wood, and to conduct the thinning and commercial cutting operations during the period between November of one year and May of the next in order to destroy the eggs and young before they enter the wood.

Worthless, scrubby, borer-infested trees should be killed outright by stripping the bark from 4 or 5 feet of the lower stem during August to prevent sprouts and seed production from them and at the same time to destroy the eggs and young borers. Trees deadened in this manner, as was demonstrated near Morgantown, W. Va., some years ago, may be so completely killed that not a single root sprout will appear. Therefore this method is of special value in preventing sprout reproduction from inferior individual trees.

COLLECTING THE BEETLES FROM GOLDEN-ROD FLOWERS.

Collecting the beetles from golden-rod flowers, by means of insect sweep nets, before they deposit their eggs, would be advisable, even for the protection of large plantations, and, as has been suggested, the planting of patches of the plant, or the cutting of all but certain strips and patches of natural growth for this purpose, would serve to concentrate the beetles where they could be caught in the nets and destroyed by emptying them into a pail containing water covered with a film of kerosene.

POISONED BAIT.

Experiments should also be made with poisoned baits, as suggested on pages 7–8.

SUGGESTIONS FOR PROPAGATING BORER-RESISTANT TREES.

FROM SEED (SEXUAL METHOD).

The fact that some trees are, to a greater or less extent, immune from attack or injury by the borer, while adjacent ones in the same grove are attacked year after year and seriously damaged, suggested the idea of breeding races and varieties of the species which would be permanently immune. This suggestion was included in the plan for cooperative investigation mentioned on pages 1–2. It was then thought that if the seed for general planting were collected from immune trees

found growing among badly damaged ones, a much larger percentage of the product would resist attack and, by continuing this method of selection and breeding, immune varieties could in time be established. There are, however, some serious difficulties to be overcome by this sexual method, especially that of cross-fertilization and variation and the very long time required to get definite verified results.

FROM ROOT CUTTINGS (ASEXUAL METHOD).

It has since occurred to the writer that insect-resistant varieties might be secured by a much shorter method, namely, that of propagating from root cuttings and possibly from twig cuttings. By this simple method of asexual propagation a large number of offspring, in every respect like the parent stock, may be secured at once for the starting of experiments to determine whether or not the asexual product of trees which have not been injured by the borer will produce plantations equally as immune. The writer's experience in the establishment of improved varieties of timothy by this method leads him to believe that insect-resistant varieties of locust can be established. If so, the principal difficulties in the problem of preventing losses from the ravages of the borer will be solved.

It should be mentioned in this connection, however, that it is possible that the borer, if deprived of the trees which are most attractive to it, may gradually adapt itself to the more resistant ones and become more or less injurious to these, and that other insect enemies may be troublesome. There will be so many advantages, however, in propagating from healthy vigorous stock that, in the writer's opinion, the matter should receive immediate attention, and selection and propagating experiments should be started at once. The success of the effort will depend largely on the proper selection of immune trees from the worst infested groves or sections rather than from those growing in partially immune localities.

Domestic animals and cultivated plants have been improved by selection and breeding to meet almost every need and requirement of man, and it is well known that some races and varieties are much less susceptible to injury by disease and enemies than are others. It is reasonably certain, therefore, that the locust will not be an exception, but that it will yield to the breeders' manipulations and may be made to produce insect-resistant varieties and forms specially fitted to supply the different needs of commercial planting, shade, and ornament.

In the meantime, much of immediate practical value and importance may be accomplished by following the suggestions herein contained for the direct control of the insect in extensive plantations and in natural forest growth.

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SOME INSECTS INJURIOUS TO FORESTS.

THE WESTERN PINE-DESTROYING BARKBEETLE.

(*Dendroctonus brevicomis* Lec.)[a]

By J. L. Webb,

Special Field Agent, Forest Insect Investigations.

INTRODUCTION.

The object of this paper is to give available information on this insect and methods of combating it, with special reference to the results of investigations by the writer during the summer of 1905 in central Idaho.

The need of the investigations was suggested in a letter dated August 10, 1904, from Mr. Gifford Pinchot, forester of the U. S. Department of Agriculture, to Dr. L. O. Howard, chief of the Bureau of Entomology, as follows:

> I learn from the Payette Lumber and Manufacturing Company, one of the Weyerhaeusers, whose land lies on the Payette River north of Boise, that the pine in their holdings is said to be dying from the attacks of insects. If it were possible for you to assign Doctor Hopkins, or one of his assistants, to make examination of this region, unless it has already been done, I should greatly appreciate it, and I should likewise appreciate your sending to Mr. Edgar M. Hoover, general manager of that company at Boise, any information you may have bearing on this subject.

In response to this request the matter was referred by Doctor Howard to Dr. A. D. Hopkins, in charge of forest insect investigations, for attention, and Mr. H. E. Burke, an assistant, was instructed to make preliminary investigations in October of the same year. In May, 1905, the writer was assigned to this work, with instructions from Doctor Hopkins to make a detailed study of the forest insects of the region, with special reference to determining the following points: (1) The relation of the several species of insects to the dying of the trees; (2) the number of species involved, the relation of each to primary and secondary attack, and the life histories of the primary and secondary enemies; (3) the extent of the infested area, the percentage of timber killed each year during the past two or three years within given areas, the approximate losses, etc.; (4) the relation of logging operations to

[a] Order Coleoptera, family Scolytidæ.

depredations by insects in adjoining forests, and the relation of time of felling timber in regular logging operations to attack by Dendroctonus and other bark and wood boring insects.

Accordingly, investigations were begun by the writer on May 17, 1905, with headquarters at Centerville, Idaho, and continued until October 10, 1905.

DEATH OF THE PINE CAUSED BY THE WESTERN PINE-DESTROYING BARKBEETLE.

Observations by the writer served to confirm the conclusion of Mr. Burke that the primary enemy was a barkbeetle identified by Doctor Hopkins as the western pine-destroying barkbeetle (*Dendroctonus brevicomis* Lec.).

CHARACTER OF THE INSECT AND ITS WORK.

The adult insect is a stout, brownish-winged beetle (fig. 7) from one-eighth to three-sixteenths inch in length, which attacks the living trees in swarms, and burrows into the living bark, through the inner layer of which each female excavates winding galleries (fig. 8 and Pls. II, III) in which to deposit eggs. These galleries serve to cut off the natural movement of the sap and completely girdle and kill the tree. In the vicinity of Centerville, Idaho, the eggs, deposited during June, July, or August, in little niches in the sides of the galleries, hatch within 4 or 5 days into small whitish larvæ (fig. 9), which mine at right angles from the primary gallery through the outer layers of the inner bark until they have completed their growth, which requires from about 20 to 30 days. They then bore into the outer corky bark (fig. 12, *a*) where they excavate little cells in which to transform, first to the pupa (fig. 10) and later to the adult. When the broods of the first generation have thus developed—in about 60 or 70 days—they bore out through the bark and fly to other trees to repeat the process and continue their depredations.

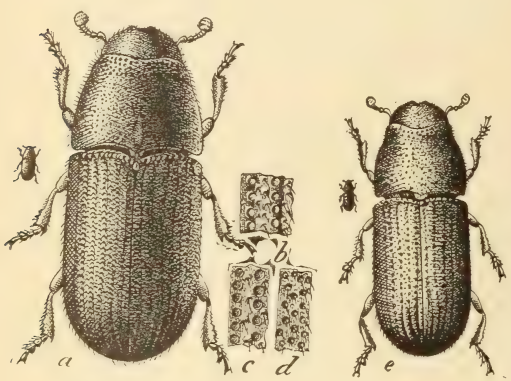
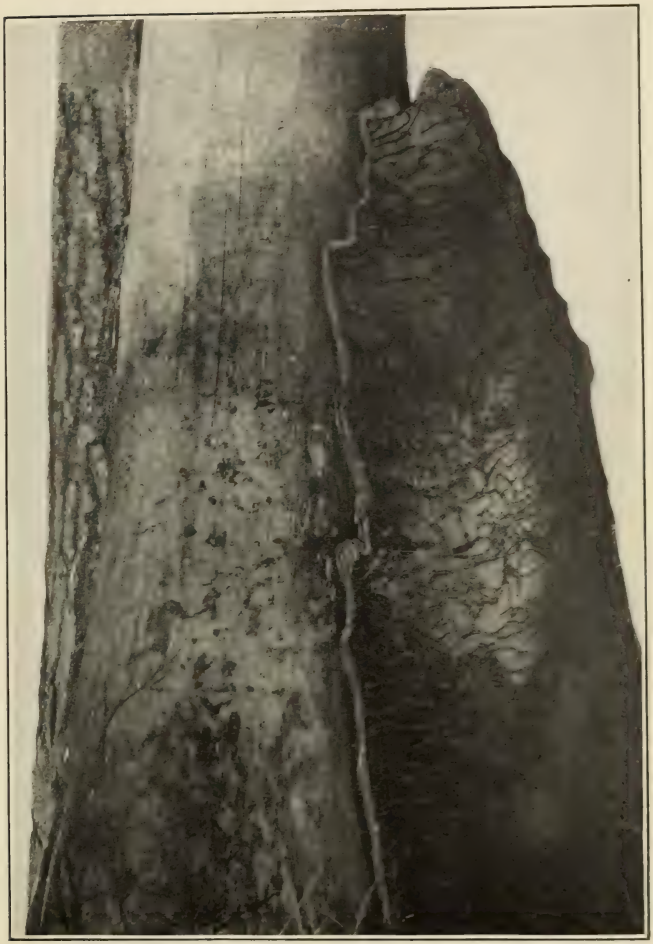


FIG. 7.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): *a*, adult female; *b*, *c*, *d*, details of punctuation; *e*, adult male. Natural size at left (original).

The presence of this destructive insect in a forest is indicated (1) by dead and dying trees scattered about or in clumps or large patches. (The dying ones, with fading yellowish and reddish foliage, are called



WORK OF THE WESTERN PINE-DESTROYING BARKBEETLE IN BARK. REMOVED FROM KILLED TREE; ALSO FAINT MARKS ON SURFACE OF WOOD. (ORIGINAL.)

WORK OF THE WESTERN PINE-DESTROYING BARKBEETLE, REMOVED FROM KILLED TREE. (ORIGINAL.)

"sorrel tops," and the dead ones, with reddish-brown foliage, are called "red tops," or, if with bare branches or broken tops, are known as "black tops" or "broken tops;"[a] (2) by small masses of resin (pitch tubes, figs. 11 and 12, *c*) in the crevices of the bark of recently attacked living trees, as well as in those of the dying and dead ones; and (3) the presence of the species is determined by removing the bark from the dying and dead trees and finding the characteristic galleries (fig. 8 and Pls. II, III).

FIG. 8.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): Galleries in the inner bark. (Original.)

It must be remembered, however, that there are many different kinds of insects, some of them closely resembling the destructive species, always found in dying pine trees. Therefore, for the general observer to be positive in the matter, specimens of insects and work should be sent to the Bureau of Entomology for authentic identification.

DISTRIBUTION.

The insect is found in southern Idaho throughout, and its range extends to the northern part of the State. It is recorded from California, Oregon, and eastern and western Washington, and, according to Doctor Hopkins, a variety occurs in Arizona and New Mexico and attacks the western yellow pine (*Pinus ponderosa*) and the sugar pine (*Pinus lambertiana*).

EXTENT OF DAMAGE AND LOSSES.

With our present knowledge of the destructive work of this insect, it is evident that a vast amount of timber has been killed by it during the past ten years within the range of its distribution. It is estimated that each year for the past two or three years, from 2 to 5 per cent of the matured standing bull pine timber within the section investigated in the summer of 1905 has died as the result of its ravages.

POSSIBILITIES OF PREVENTING LOSSES.

With our additional knowledge of the life history and habits of the beetle, we are able to suggest practical methods of controlling it and of preventing a large percentage of the losses heretofore caused by its depredations.

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[a] See Bul. 56, Bur. Ent., U. S. Dept. Agric. The Black Hills Beetle.

EARLY HISTORY OF THE SPECIES.

LeConte, in 1876, described the species under the name *Dendroctonus brevicomis* from a single specimen collected in middle California. Dietz, 1890, considered *D. brevicomis* the same as the southeastern species, *D. frontalis* Zimm. Hopkins, 1899, concluded that it was distinct from *D. frontalis*, and therefore that the old name should be retained.

It appears that previous to 1899 nothing had been recorded in regard to the habits and life history of this insect, and that, therefore, the earliest records were made in 1899 by Hopkins, who found it associated with dying sugar pine and western yellow pine at McCloud, Cal., on April 21, 1899, and the next day at Grants Pass, Oregon, with several hundred pine trees which had evidently died from its attack. On May 20, also, at Buckeye (near Spokane), Wash., many trees were found which were dying, or had died, as evidenced by the abundance of the insects and the extent of their work, and on June 6, at Cedar Mountain, Idaho, Doctor Hopkins found it in the bark of pine trees which had been defoliated the previous year by the caterpillars of the pine butterfly (*Neophasia menapia* Feld.). He found also that this beetle was quite intimately associated with the destruction of a large amount of timber only partly defoliated by the caterpillars.

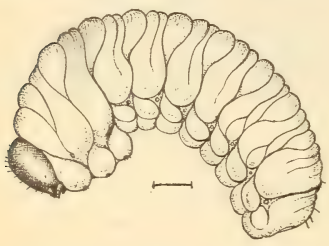

FIG. 9.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): Larva. Line below represents natural length (original).

Under his discussion of the principal scolytid enemies of the forests in the Northwest, Doctor Hopkins refers to this species as follows:[a]

Dendroctonus brevicomis Lec. was found to be a most destructive enemy of the yellow pine (*Pinus ponderosa*) in northern California, southern and eastern Oregon, northeastern Washington, and western Idaho. A large amount of some of the finest timber in all of these localities had died within the past seven or eight years, evidently as a direct result of attacks by this bark beetle. It was also found to attack and prevent the recovery of trees injured by defoliating insects and other causes. Its habits and the character of its galleries appear to be identical with those of *Dendroctonus frontalis*, which is noted for its destruction of vast quantities of pine and spruce timber in West Virginia and adjoining States between 1890 and 1893. It is killing the western yellow pine just as *D. frontalis* commenced to kill the eastern yellow pine (*Pinus echinata*) before it spread to all the other pines and spruce. Therefore, just as *D. frontalis* has proven to be the most destructive enemy of eastern conifers, the western representative of this species will doubtless prove to be, under similarly favorable conditions, equally as destructive to the western forests in which the conifers predominate.

Among the most important features observed regarding the habits of this beetle was the fact that it is attracted to trees girdled by settlers and farmers in the process of clearing land, and that in the bark of such trees it breeds and multiplies in sufficient numbers to enable it

[a] Bul. 21, n. s., Div. Ent., U. S. Dept. Agric., 1899.

to attack and kill the timber in adjoining healthy forests. Indeed, my observation leads me to conclude that a considerable number of girdled pine trees may easily form a nucleus for a destructive invasion by it.

In the same bulletin, under the head of "The western yellow pine," he says:

It has in *Dendroctonus brevicomis* a most pernicious enemy, which penetrates and excavates winding galleries through the living bark of the finest trees, thus speedily causing their death. Very many trees have died and are dying from this cause, and the dead ones are contributing to the spread of forest fires.

Specimens of the insect and its work occupied a prominent place in the exhaustive exhibit of insect enemies of forests and forest products at the Louisiana Purchase Exposition at St. Louis, in 1904, and the Lewis and Clark Centennial Exposition at Portland, Oregon, in 1905, and were referred to in the catalogues of the exhibits by the Bureau of Entomology.[a]

OBSERVATIONS BY HOPKINS, 1899-1904.

The following summary relating to this species, prepared by Doctor Hopkins from his field notes, includes many facts which have not been published and which have a direct bearing on the life history and habits of the species in different sections of the country where it is found:

McCloud, Cal., April 21, 1899.—Work and dead adults were discovered in a sugar pine log, evidently from a tree which was dying when felled; also dead parent adults in primary galleries, and larvæ and pupæ abundant in outer bark of large dying western yellow pine with the characteristic appearance of eastern pines when dying from the attack of the destructive pine barkbeetle, *D. frontalis*. A few immature adults were found in the outer bark, and evidence that some had emerged. This evidence was in the form of apparent exit holes in the bark, which may have been ventilating holes from main galleries, for with our present knowledge it is not likely that any adults could have emerged so early.

Grants Pass, Oregon, 1899.—On April 24 numerous dying western yellow pine trees were found here scattered through the forest where a severe windstorm had blown down much large timber on September 24, 1895. Young adults, larvæ, and pupæ were found in the outer bark of the standing trees which had evidently been attacked and had commenced to die the previous fall. April 25, numerous trees were observed which died the fall before and others which were not yet dead. One group of 30 young trees about 2 miles north of town were dying at the top, the leaves turning yellow and brown. All trees, without exception, were either infested or had been infested with *D. brevicomis*, and every indication pointed to this species as primarily to

[a] Buls. 48 and 53, Bur. Ent., U. S. Dept. Agric.

blame for the trouble. There were many trees which had been dead for from 3 to 10 years, and in the bark of those dying within the past 4 years traces of the characteristic galleries of *D. brevicomis* were found. No large bodies of timber had died, but the dead and dying trees were scattered all through the forest. A few examples of adults were found mining in living bark of a dying tree, where they had evidently passed the winter, since none of the broods had sufficiently matured to emerge. April 26, eight large trees—five western yellow pine and three sugar pine—which had evidently died in 1897, were observed in the Slate Creek Valley. The western yellow pine exhibited abundant work of *Dendroctonus brevicomis*, and the sugar pine the work of both this and a larger species of the same genus (*D. monticolæ*).

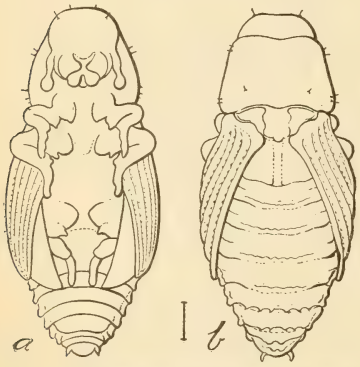

FIG. 10.—The western pine-destroying bark-beetle (*Dendroctonus brevicomis*): *a*, pupa, ventral view; *b*, same, dorsal view. Vertical line in center represents natural length (original).

Buckeye, Wash. (near Spokane), May 22.—A small western yellow pine tree, evidently killed by the insects, was found. None of the brood had emerged, having died in the bark, possibly from the effects of unfavorable climatic conditions. In another tree killed by this species at this place, young living adults were found.

Cedar Mountain, Idaho (near Moscow), June 4.—The bark of western yellow pine trees defoliated by pine butterfly larvæ was found to be infested by larvæ and pupæ of *D. brevicomis*. Dead parent adults, also, were found in the primary galleries.

Mariposa County, Cal., June 9, 1904.—Fragments of dead adults were found in primary galleries in bark of a large western yellow pine tree, evidently killed by this species.

Yosemite Valley, California, June 13, 1904.—Western yellow pine trees cut between September 20 and 24, 1903, were found to be thickly infested with larvæ of this species from eggs evidently deposited in September or October.

OBSERVATIONS BY H. E. BURKE, 1904.

From October 20 to 26, 1904, Mr. Burke found the work of this species on western yellow pine quite abundant in the region of Smiths Ferry, Idaho. Under date of October 26 he records observations regarding this barkbeetle in a western yellow pine tree 3 feet in diameter felled some time during that summer; the foliage and bark were living, but red borings on the bark showed where insects had entered. Adults of the Dendroctonus were present in short winding galleries

in the living inner bark, two adults to a gallery. Eggs occurred singly in niches on the sides.

He estimated that as a result of the work by this insect near Smiths Ferry 30 per cent of standing timber was dead and 5 per cent was dying. This was at the worst point of infestation, but scattered dying timber was found all over Boise and Payette basins. The same condition extended into the Bitter Root Forest Reserve.

OBSERVATIONS BY THE WRITER, 1905.

The investigations by the writer during the summer of 1905, so far as they related to this species, were mainly for the purpose of determining the principal facts in its life history and habits in the vicinity of Centerville and Smiths Ferry, Idaho. The results may be summarized as follows:

LIFE HISTORY AND HABITS OF THE INSECT.

HIBERNATION.

While it is probable, as observed by Hopkins at Grants Pass, Oregon, that a few parent adults which enter the bark in the fall may pass the winter in that stage, it appears that it is in the young to matured larval stages that the insect normally passes the winter, each individual in a separate mine or cell in the outer corky bark of the tree in which it developed the previous summer and fall. The earliest observations at Centerville were made on May 18, when larvæ, pupæ, and young adults were found. Some of the larvæ were small, but the majority of them were mature and ready to change to pupæ. The pupæ and adults had evidently transformed from larvæ since the beginning of activity in the spring.

The latest date on which larvæ of the hibernating broods were found was June 13. Pupæ were found as late as July 3, and adults July 7. It is therefore evident that the majority of the over-wintering broods develop to the adult stage by about the middle of June, but broods from eggs deposited late in the fall may not develop until nearly the middle of August. Adults begin to emerge in the latter part of May and continue to do so through June and July and into August. Thus the period of activity of the hibernating broods at Centerville is probably from the first warm days in April and May until about the last of July—approximately 90 days—the majority, however, coming out in June and in early July.

FIRST GENERATION.

The first generation at Centerville begins with the first eggs deposited, apparently about the last of June, by the adults developed from hibernating larvæ and pupæ. These eggs hatch in about 4 days after deposition. The principal egg-laying period for this generation is evidently between the latter part of June and the first part of August.

It would appear that the length of time spent in the larval state is from 31 to 35 days. Sometimes, however, a few individuals of this first generation, either from retarded development or other causes, do not go through their transformations with the rest of the broods, but remain as larvæ all through the fall and winter, evidently changing to pupæ in the following spring.

The length of time spent in the pupal stage is approximately 15 days. Pupæ of this generation were observed in different broods from August 14 to September 6.

The first adults, evidently of this generation, were observed in the bark August 14. The length of time spent in the bark after reaching this stage appears to be from 7 to 14 days. It is difficult to tell just when the emergences cease, as the last individuals of the brood come out scatteringly. Thus, on October 10 a few adults were still found in the bark. As this was the last observation, it is not known whether adults emerged later in the fall or whether they passed the winter in the bark before emerging; but the latter was probably the case. In one tree under observation eggs were deposited July 6 and the broods developed and emerged by August 28, a period of 53 days. Thus it appears (1) that the first generation begins with eggs deposited probably in the latter part of June; (2) that the majority of the broods develop and emerge by the first part of September (a period of about 60 days), but that some may continue to develop and emerge until in October; and (3) that possibly some pupæ and young and matured adults may hibernate along with the larvæ. Thus it may require 300 to 390 days or more for the complete development and emergence of some individuals of the first generation.

SECOND GENERATION.

Eggs deposited by adults of what appears to have been the first generation were found August 26 and as late as September 13. It will therefore be seen that there is a partial overlapping of the periods of the two generations.

Larvæ were found as early as September 4, and on October 10, when the last observation was made, some larvæ were apparently full grown.

No pupæ or adults of this generation were found up to the time of the writer's last observations—on October 10, 1905. Mr. Burke found adults, but probably of the first generation, excavating galleries and depositing eggs as late as October 26, 1904. Thus it appears that the second generation, beginning with the first eggs deposited by adults of the first generation, passes the winter in the larval stage and develops and emerges by the middle of the following June to the first part of July. It therefore occupies a period of about 315 to 330 days, including about 60 days of activity in the fall, 165 days of hibernation, and 90 to 105 days of activity in the spring and early summer.

It is probable that at higher elevations and farther north the majority of the broods would not develop in much less than a year's time and that at more southern and warmer localities in the Pacific Coast region there would be two complete generations and possibly a partial third.

FIG. 11.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): Pitch tubes on bark of tree. (Original.)

HABITS.

When first transformed, in May and June, the young beetles have very soft, delicate tissues. They therefore remain in their pupa cases until their bodies are fully hardened or chitinized. When nearly ready to emerge, the adults bore their way almost to the surface of the bark (fig. 12, *a*), but pause before emerging, appearing to rest in the burrows they have just made. They do not, however, hollow out the space immediately adjoining the pupa case, as is the habit of another species of this genus. When quite ready to emerge, the beetles continue their burrows out through the remaining portion of the bark. The individuals of a brood do not appear to emerge simultaneously, but they come forth at irregular intervals until all are out, leaving the bark thickly punctured with small, round, clean-cut holes, as shown in figure 12.

After leaving the tree or trees in which they went through their transformations the beetles fly away to find trees in which to deposit eggs. They may select trees close at hand or may fly quite a long distance before making a selection. They will also enter the living bark of recently felled trees. Large numbers of

the beetles usually settle upon a few trees close together and crawl about upon the bark from near the base to about two-thirds of the distance to the tree's top, seeking suitable places for entrance. Crevices in the bark are favorite places with them for this purpose. The female appears to bore the entrance hole in the bark, and may or may not be closely followed by her mate. In some cases where galleries had just been started, females were found alone, that is, one female to a single gallery. In others, the female was followed by the male. As the first incision is made into the living inner bark, the tree begins exuding pitch to cover the wound made by the intruding beetle. This pitch or resin collects at the mouth of the entrance hole in the form usually known as a pitch tube (figs. 11 and 12, *c*). Where the attacking force of beetles is small, the efforts of the tree to heal these wounds not infrequently succeed, the flow of pitch being so great as to overcome and suffocate the beetles. In such cases the dead beetles may be found in the pitch masses after the tree has recovered. Where the attacking force is large, however, the flow of pitch does not seriously hinder the beetles. After completing the egg laying, the parent adults remain for some time in the galleries and excavate irregular branching burrows toward the end farthest from the entrance, where they remain until they die.

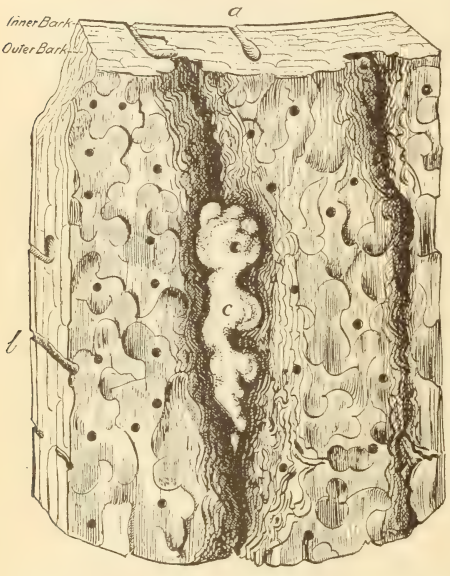

FIG. 12.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): *a*, hibernating or transformation cell; *b*, exit burrow; *c*, pitch tubes and exit holes. (Original.)

After successfully effecting their entrance into the bark, the females excavate, through the inner layer of bark, winding, irregular galleries, which run into and cross each other many times (fig. 8). The eggs are laid at the sides of the gallery, each in a little niche hollowed out to receive it and packed in with the borings made in excavating the gallery.

Almost immediately after hatching the larva begins feeding upon the cambium surrounding the niche in which it hatched. For a few days it remains in the cambium, then bores out toward the outer bark. As it progresses, it is at the same time growing, and this growth is indicated by its constantly widening mine or burrow, which

is made larger to accommodate the size of the body. Having reached the outer bark, it hollows out an oval space or pupa case, in which to go through its transformations.

NATURAL ENEMIES.

INSECTS.

Larvæ of the predaceous beetles of the genus Clerus, which are known to prey upon Dendroctonus larvæ, were quite common in and under the bark of the infested trees, and they doubtless help to some extent in keeping down the numbers of the barkbeetles.

BIRDS.

Birds contribute their part also in destroying larvæ and pupæ. The work of woodpeckers was found upon most of the trees which had been killed by *D. brevicomis*, and these birds had evidently destroyed a large percentage of the insects in some of the trees.

METHODS OF COMBATING THE INSECT.

FIRST RECOMMENDATIONS.

The following information and recommendations relating to this insect and methods of preventing losses from its ravages were conveyed by Doctor Hopkins to Mr. E. M. Hoover, of Boise, Idaho, manager of the Payette Lumber and Manufacturing Company, in a letter dated January 23, 1906, and afterwards published, with Mr. Hoover's reply, in a local newspaper.

Our special field agent, Mr. J. L. Webb, has submitted his report on forest insect investigations in the vicinity of Centerville and Smiths Ferry, Idaho, during the past summer, and it will interest you no doubt to know that the insect which is primarily to blame for the death of pine trees was located and thoroughly studied by him.

He found that the broods of the destructive species pass the winter in the grub state in the bark of trees which died during the late summer and fall and that they do not transform to the winged form and emerge until after the 1st of May. Therefore the method of combating the pest is simply to cut the infested trees any time between the 1st of October and the 1st of May and to remove the bark from the main trunk and burn it.

It is necessary to burn the bark in order to kill the broods of this insect, because they occupy the intermediate portion between the inner surface and the outer scale portion; hence the drying of the removed bark will not kill them as it would if they occupied the inner moist portion.

The infested trees can be located (1) by the yellowish and light reddish brown color of the foliage; (2) by cutting into the bark as high up on the trunk as a man can reach with an ax to determine whether the middle portion of the bark is infested with the small white grubs, which are about three-sixteenths of an inch long. If these are found, it will be conclusive evidence that the tree has been killed by the beetle and is infested with its broods. It must be remembered that there are hundreds of other kinds of insects which occupy the *inner* portion of the bark and wood of such trees, but none of the smaller ones pass the winter in the *outer* bark. * * *

Perhaps the most important thing for you to do as a preliminary to any definite action you may take in the matter is to have a number of intelligent cruisers make a survey of your holdings for the purpose of locating the principal sections in which trees have died during the

past summer and the location of the larger clumps and patches of infested trees within such sections; then, if the locations of the infested areas and clumps are indicated on a map, it will aid materially in planning effectual operations. If you could conduct your logging operations in these sections and utilize the infested trees the desired results would be accomplished without much expense. It is not necessary that all scattering infested trees should be felled and barked, but it is of the greatest importance that all of the larger clumps and patches within the worst infested areas should be thus treated within the period mentioned. If this can not be done this year, the work of locating infested areas should be conducted next summer (1906), in order that the more important sections may receive attention next fall and winter.

We shall hold ourselves in readiness to give you further information and suggestions on subjects which may not be clear to you, and whenever there is doubt about the insect or its work specimens should be sent to us for authentic identification.

In response to this letter, Mr. Hoover wrote:

We are most gratified with the information given us and feel that it will be of much value to us in our woods operations. * * *

The ferreting out of the insect pest and advising a way to combat it is a work of great value to the country and of especial interest to all persons interested in forests, and we wish to add our word of appreciation of the service of your Bureau.

Your letter is clear and explicit, and we will be glad to take advantage of your suggestions in our logging operations and have conveyed the information to other lumber companies operating in this vicinity.

Doctor Hopkins has, since then, prepared the following additional recommendations and summary:

TRAP TREES.

With our present knowledge of the life history of the western pine-destroyer and its habits of attacking girdled and felled trees, it is evident that trap trees[a] may prove effective in keeping the insect under control, especially in localities where only a few trees are being killed each year or after a large number of the infested trees have been felled and barked in a badly infested locality.

The time to girdle and fell trees to catch the first generations would be about the middle of June, the bark to be removed and burned in about 20 to 25 days, or before the broods emerge. Girdled or deadened trees are prepared by the "girdle to heartwood" method—that is, cutting through the sapwood all around the trunk 3 or 4 feet above the base or as high above the base as convenient to chop; for this purpose large, inferior trees should be selected.

Felled trees should be lodged or allowed to fall on logs, rocks, etc., so that the prostrate trunks will be as far as possible from the ground. Trees prepared in this manner will usually be attacked by swarms of the beetles, which will excavate galleries in the bark and deposit their eggs. After the eggs have hatched and the larvæ are about full grown, the removal and burning of the bark will effectually destroy the broods and thus contribute greatly to reducing the numbers of the beetles—

[a] Living trees girdled or felled at the proper time to attract the flying beetles to them and away from healthy trees.

which must occur in large numbers before they can attack and kill a tree. Some of the living trees in the immediate neighborhood of the trap trees may be attacked by beetles attracted to the vicinity by the felled or girdled trees. These should be felled and treated the same as trap trees.

If the conditions appear to warrant it, additional trees should be girdled or felled about the first part of August to catch the second brood. These may be barked, to kill the broods, any time between the first part of October and the first part of the following May.

SUMMARY.

HABITS AND LIFE HISTORY.

The western pine-destroying barkbeetle usually attacks and kills the best examples of western yellow pine and sugar pine.

If neglected and under certain conditions favorable to the species, it is capable of devastating the pine forests over large areas. The broods of the beetle pass the winter in the outer bark of trees killed by it the previous summer. The adults of the overwintering broods emerge and fly in May, June, and July, the beginning and ending of the period varying with the seasons, latitude, and altitude.

The first eggs from the first generation are deposited in June or July, and in some of the warm localities possibly as early as the middle of May. In localities intermediate between the colder and warmer regions the majority of the adults of the first generation evidently develop and emerge in August, but some individuals may remain in the trees until June of the next year.

The first eggs of the second generation are evidently deposited in August and September, depending on locality, and it would appear that in intermediate localities all of the broods of this generation pass the winter (hibernate) in the larval stage in the outer bark. In the warmer localities some of them may develop and emerge in the fall, while in the colder localities there may be but one generation.

The first evidence of attack on living trees is the presence of pitch tubes (figs. 11 and 12, *c*) on the bark or of reddish borings lodged in the crevices and around the base of the tree.

During the fall, winter, and following spring, after a successful attack, the infested trees will be indicated by the fading yellowish and reddish leaves.

The work of the insect will be indicated by the winding galleries through the inner bark (fig. 8). Trees from which the broods have emerged will be indicated by large numbers of small holes through the outer bark (fig. 12).

REMEDIES.

The principal areas of infestation and the principal patches of infested trees should be located in September and October.

Beginning with the first part of October, the infested trees should be felled and the bark removed from the main trunk and burned, these operations to be completed by the first part of the following May.

If all of the trees within a given area can not be thus felled and treated, the work should be concentrated on the larger clumps and patches of infested trees.

The cost per tree for cutting, barking, and burning the bark will range from about 30 cents to $1, depending on locality and accessibility.

Summer cutting, except in regular logging operations, is undesirable, since the cutting of a few trees in the midst of a large forest may attract the insects from a long distance, and thus result in extensive depredations in bodies of timber which it is most desirable to protect.

TRAP TREES.

In sections where it is known that the beetle is killing some of the timber, trap trees should be provided in June and August. Ordinarily, 4 or 5 inferior living trees within each section, on which there is evidence of the work of the beetle, should suffice.

Trap trees should not be prepared unless it is reasonably certain that the bark will be removed and burned before the broods of the beetles develop and emerge, otherwise such trees may contribute to the destruction of a larger amount of timber.

STORM-FELLED OR LIGHTNING-STRUCK TREES.

Storm-felled and lightning-struck trees are a menace to a healthy forest within the distribution of this insect, since they serve as breeding places and centers of infestation. Therefore, whenever practicable, such trees should be watched, and if found infested with broods of this beetle, they should be treated as recommended for infested and trap trees.

PUBLICATIONS RELATING TO THE WESTERN PINE-DESTROYING BARKBEETLE.

1876. LeConte, J. L.—The Rhynchophora of America North of Mexico. Proc. Am. Philos. Soc., Vol. XV, Dec., p. 386. Species described.

1890. Dietz, W. G.—Notes on the species of Dendroctonus of Boreal America. Trans. Am. Ent. Soc., Vol. XVII, p. 32. Revision notes.

1899. Hopkins, A. D.—Preliminary Report on the Insect Enemies of Forests in the Northwest. Bul. No. 21, n. s., Div. Ent., U. S. Dept. Agric., pp. 13–15. First notes on habits.

1904. Hopkins, A. D.—Catalogue of Exhibits of Insect Enemies of Forests and Forest Products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. Bul. No. 48, Div. Ent., U. S. Dept. Agric., p. 18. Character of work described.

1905. Currie, R. P.—Catalogue of the Exhibit of Economic Entomology at the Lewis and Clark Centennial Exposition, Portland, Oregon, 1905. Bul. No. 53, Bur. Ent., U. S. Dept. Agric., pp. 74 et seq. Reprinted from Bul. 48.

U. S. D. A., B. E. Bul. 58, Part III. F. I. I., March 5, 1907.

SOME INSECTS INJURIOUS TO FORESTS.

ADDITIONAL DATA ON THE LOCUST BORER.

(*Cyllene robiniæ* Forst.)[a]

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

This part of Bulletin 58 contains a partial revision of Part I, with additional information based on the results of subsequent investigations by the writer and one of his assistants, Mr. W. F. Fiske.

SEASONAL HISTORY.

The data under this head refer to the District of Columbia and vicinity, latitude 39°, altitude 10 to 90 feet above tide.

HIBERNATION.

Hibernation begins soon after the larvæ hatch from eggs deposited at various times from August to October, and the period is passed as minute larvæ, scarcely longer than the eggs from which they hatch, in small individual hibernating cells excavated by them just beneath the corky bark and in the outer layers of the living bark on the main trunk of the larger to small trees or small saplings, and larger to small branches.

ACTIVITY OF THE OVERWINTERED LARVÆ.

Activity of the overwintered larvæ begins in April, or with the beginning of the movement of the sap in the bark and just before the leaf buds open. In 1906 activity began April 11; on April 13 the more advanced individuals had entered to the wood, on the 16th were grooving the surface, and on the 25th some of them had entered the wood. By May 11 nearly all of them had entered the sapwood and some of them had extended their burrows into the heartwood and were rapidly

[a] Order Coleoptera, Family Cerambycidæ.

increasing in size and very active, so that by May 20 some of them were more than half grown. They continued actively feeding and growing until after the middle of July, when they began to transform to pupæ and continued transforming during August until all had transformed, probably by the 1st of September. The pupæ begin transforming to adults about the 1st of August and continue transforming probably into September, although the principal transformation is in August.

ACTIVITY OF THE ADULTS.

The adults begin to emerge as early as the 7th of August, and continue emerging until the last of September, the greater number coming out during the last part of August and the first half of September. Evidently all beetles are out by the first week in October.

The females begin to deposit eggs within a few hours after they emerge. The principal period of oviposition appears to be between the middle of August and middle of September, but oviposition continues until in October. The eggs hatch within eight or ten days after they are deposited, and the young larvæ excavate their hibernating cells and remain dormant until the following spring.

VARIATION IN SEASONAL HISTORY BETWEEN DIFFERENT LATITUDES AND ALTITUDES.

Phenological investigations of plants and insects by the writer[a] during the past ten years indicate that the average difference in the dates of occurrence of the different stages of *Cyllene robiniæ* at different latitudes and altitudes in the eastern United States will not be far from four days later for each degree north of latitude 39° and for each 400 feet of altitude above Washington at the same latitude, or four days earlier for each degree south of latitude 39° at the same altitude.

Thus, at latitude 43° in central New York, or central Michigan, with altitude the same as at Washington, the dates would be about sixteen days later, and at altitudes of 1,000 feet at latitude 43° they would be about twenty-six days later; at the same altitude as that of Washington at latitude 35° in southern North Carolina and Tennessee they would be about sixteen days earlier or at 1,600 feet elevation about the same. Thus we would have about thirty-two days' difference between localities at the same altitude in central New York and southern North Carolina. We would also have thirty-two days' difference between Washington and localities at latitude 39° and altitudes of 3,200 feet in the mountains of Virginia and West Virginia.

[a] Bull. 50, W. Va. Agric. Exp. Sta., 1898, pp. 17, 18, and Bul. 67, 1900, pp. 241–248, with map.

HABITS OF LARVÆ AND ADULTS.

When a larva begins activity in the spring it molts and proceeds to excavate an independent food and entrance burrow through the dead area of bark surrounding the hibernating cell or through the living bark immediately surrounding the dead area, until it reaches the cambium. It then excavates an irregular groove or cavity in the outer sapwood, returning frequently to the outer cell or opening to push out the borings and apparently to get relief from the exuding sap. A large per cent of the larvæ die before any further progress is made, but survivors grow rapidly and soon succeed in overcoming the many obstacles, including natural enemies, resistance of the tree, etc., and enter the sapwood. From this stage on until the larvæ have attained their full growth they are very active and destructive. Their food consists principally of the nutritious substances of the bark and wood, and probably of the liquids flowing into the burrow, but they do not hesitate to kill and feed upon each other when two or more come in contact within the same burrow. The fact that the entire development often takes place in a burrow scarcely more than twice the length of a matured larva indicates that food must be obtained from some source other than the wood and bark. Throughout its active life the larva frequently returns to the inner and outer bark to enlarge the burrow, and push out its borings, so that the burrow when completed is of a diameter throughout sufficient to allow the passage back and forth of the full-grown larva. When full grown the larva enlarges the inner end of the burrow, plugs the outer portion with boring chips, and in due time transforms in succession to the pupa and adult. When the adult is fully matured it escapes through the exit prepared by the larva. Immediately after a female emerges she is joined by one or more males, and within a few hours, or within twenty-four hours, she proceeds to deposit eggs. She runs about over the bark investigating the crevices, by means of her ovipositor, to locate those most suitable for an egg. Sometimes as many as twenty places are critically examined before one is selected, and it appears that but one egg is deposited in a place by the same female, but other females may find the same place and each deposit an egg, so that sometimes several eggs are found in one crevice. As a rule, however, there is but one. The faculty of the female in locating the most suitable place for an egg by means of the sensitive palpi on the tip of the ovipositor is remarkable.

The beetles feed principally on pollen from the flowers of golden-rod, but are very fond of any sweet liquid, such as sugar sirup placed on the trunks of the trees. They are found during the day on the trunks,

branches, and foliage of the locust, and during their principal period of activity, from toward the last of August to the middle of September, they are especially common on the golden-rod flowers. Mr. Fiske determined that they were also actively copulating and depositing eggs as late as 10 o'clock at night.

The attack of this insect is apparently confined to the black or yellow locust (*Robinia pseudacacia*).

ECONOMIC FEATURES.

DESTRUCTIVE CHARACTER OF THE WORK.

The destructive character of the work of the locust borer is a matter of great economic importance. This insect attacks the otherwise perfectly healthy trees, and in addition to causing the detrimental wormhole defects in the wood it often kills the trees or renders an otherwise valuable product worthless except for fuel. It is much more destructive in some localities and sections than in others, and also much more destructive to some trees in the same grove than it is to others. It is more destructive also to young saplings and the branches of medium-sized trees than to the larger trees.

The death of a tree is caused principally by injuries to the inner bark and cambium, resulting from repeated attacks. Injuries to the wood alone do not result in the death of trees except when all of the wood is practically destroyed or sufficiently injured to cause the tree to fall or be broken down by the wind.

The commercial value of the wood product is diminished or destroyed by the wormhole defects, but for certain purposes, as, for instance, fence posts, a limited number of such defects are not detrimental, except so far as they may contribute to decay.

EVIDENCES OF ATTACK.

The first evidence of attack is fine brownish boring dust and wet spots on the bark, first observed in April, when the overwintered larvæ begin to enter the inner bark. As soon as the larvæ begin to groove the surface of the wood and enter the sapwood, their presence, in addition to the wet spots, is indicated by yellowish boring dust mixed with liquids and the gum-like exudations. After all of the larvæ have entered the wood their presence is plainly shown by the quantities of yellowish boring dust lodged in the loose bark on the trunk, in the forks of the tree or branches, and around the base. At this stage, usually about the middle of May, the badly infested trees which will die are plainly indicated by the failure of the leaf buds to open, or by the dwarfed or faded and sickly appearance of the foliage, and toward the last of the month and until the larvæ have completed their work in July, by the breaking down of the branches and small trees.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR DESTRUCTIVE WORK.

Favorable conditions for the destructive work of the borer appear to be found in the presence of isolated trees and groves in the open in localities where golden-rod is present or abundant; also, where less resistant varieties of the tree prevail.

Unfavorable conditions are found in forest growth or large areas of pure stands, or mixed stands where the locust predominates; also, in plantations and groves where resistant varieties prevail, and where there is no golden-rod or other favorite food for the beetles. It is also found that coarse, thick bark is less favorable than the thinner bark on old and young trees and saplings.

NATURAL ENEMIES.

INSECTS.

Several predaceous insect enemies of the larvæ have been observed, but so far no true parasites have been discovered. A large elaterid larva (*Hemirhipus fasciculatis* Fab.) appears to be the principal enemy of the borer after the latter has entered the wood. It resembles the borer somewhat, but is easily distinguished by the more flattened and shiny body, long prothoracic legs and two curved spines on the last abdominal segment. This predaceous larva is frequently found in the empty mines of the Cyllene larvæ, therefore it is evidently an enemy of considerable importance.

A slender, cylindrical, whitish, footless dipterous larva of an undetermined species is sometimes found in the mines in the wood, and, according to an observation made by Mr. Pergande, it may attack and kill the borers.

Whitish, flattened larvæ of the nitidulid genus Ips, with prominent branched hooks on the last abdominal segment, are common in the sap at the entrance of the mines and in the burrows made by the young borers in the inner bark and outer wood. They are supposed to be sap feeders, but the writer found they would attack and devour young Cyllene larvæ when confined together in a bottle. Therefore it is possible that they kill a great many of the young borers before these enter the wood, which may account, in part, for the disappearance of such a large number of the young borers while in the bark-boring stage.

It was also demonstrated that if several young Cyllene larvæ of various sizes were placed together in a small vial, the larger ones would kill and eat the smaller ones. It is probable, therefore, that when several larvæ hatch from a cluster of eggs and but one survives—which is usually the case—the larger or stronger one has killed the weaker ones.

DISEASE AND SAP FLOW.

Dead larvæ are frequently found in the mines, covered with white flour-like spores, and sometimes these spores are so common that a perceptible cloud rises from the wood when it is split open. Experiments in placing some of the spores with healthy uninjured larvæ in bottles, as well as with those in the normal position in the wood, resulted in the death of the larvæ and the development of apparently the same disease, while the duplicate larvæ kept under the same conditions, but without contact with the spores, remained normal and healthy. Therefore this is a fungus which will kill the borers and one which is evidently of considerable importance.

The profuse flow of sap together with a gummy substance in the wounds made in the living bark and cambium is evidently detrimental to the normal progress of the young larvæ and apparently many of the latter are thus destroyed.

METHODS OF CONTROL.

It should be remembered that all the holes found in a tree and all other damage by the borer are not the work of one generation, but usually that of repeated annual attack during the life of the tree; also, that a burrow in the sapwood of a young tree remains the same burrow in the heartwood of the old tree, without change, as long as the tree exists, except in the healing of the original entrance. The number of borers and the annual amount of damage is not so great, therefore, as might appear, and, while each female is capable of depositing a hundred eggs, only a small percentage of the larvæ hatching from them survive the bark-infesting stage or complete their development to adults. This suggests that any method of management which will insure the destruction of a large per cent of the surviving larvæ and beetles each year will reduce the damage to a point where there will be practically no loss.

With our knowledge of the life history and habits of the insect it is now possible to make definite recommendations and suggestions for its control. Some of those of immediate practical importance are as follows:

TIME TO CUT LOCUST TO DESTROY THE YOUNG LARVÆ.

The cutting of locust for all purposes, including thinning operations and for private or commercial use, should be done during the period between the 1st of October and the 1st of April, the bark removed from the crude product, such as posts, poles, and the like, and the tops and thinnings burned. The removal of the bark from all desirable portions of the trunks of the trees felled during this period is important and necessary in order to destroy the larvæ before they

enter the wood. The work in all cases should be completed before the leaf buds begin to swell on the living trees in the spring.

DESTRUCTION OF INFESTED TREES AND WOOD.

When it is desirable to simply remove and destroy, by burning or otherwise, the badly infested and damaged trees to kill the broods of larvæ, the work should be done in May and June, when all such trees can be easily recognized by the boring dust, fading leaves, broken branches, etc., and must be completed before the beetles begin to emerge. Perhaps the best rule, applicable to all localities, latitudes, and elevations, is to complete the work by the time the flowers have all fallen from the trees, which will vary between different altitudes and latitudes from about the middle of May to the last of June. Another rule would be to complete the work before the earliest varieties of golden-rod begin to show evidences of flowering. This, however, would be the latest that the work should be done, because the beetles begin to emerge by the time the first golden-rod flowers appear.

SPRAYING THE TRUNKS AND BRANCHES TO KILL THE YOUNG LARVÆ.

Experiments have demonstrated that the hibernating larvæ may be killed by spraying the trunks and branches with a strong solution of kerosene emulsion. Therefore, when it is practicable or more desirable to adopt this method for the protection of small plantations, groves, or shade trees, the spraying should be done in the fall or winter, not earlier than November 1, and not later than April 1—in other words, during the dormant period of the tree. The following paragraphs, relative to the preparation of kerosene emulsion, are taken from Farmers' Bulletin No. 127, by C. L. Marlatt:

Kerosene emulsion (soap formula)—

Kerosene	gallons..	2
Whale-oil soap (or 1 quart soft soap)	pound..	½
Water	gallon..	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added, boiling hot, away from the fire, to the kerosene. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely, and should be diluted only as wanted for use.

For the treatment of large orchards or in municipal work requiring large quantities of the emulsion, it will be advisable to manufacture it with the aid of a steam or gasoline engine, as has been very successfully and economically done in several instances, all the work of heating, churning, etc., being accomplished by this means.

The use of whale-oil soap, especially if the emulsion is to be kept for any length of time, is strongly recommended, not only because the soap possesses considerable

insecticide value itself, but because the emulsion made with it is more permanent, and does not lose its creamy consistency, and is always easily diluted, whereas with most of the other common soaps the mixture becomes cheesy after a few days and needs reheating to mix with water. Soft soap answers very well, and 1 quart of it may be taken in lieu of the hard soaps.

In limestone regions, or where the water is very hard, some of the soap will combine with the lime or magnesia in the water and more or less of the oil will be freed, especially when the emulsion is diluted. Before use, such water should be broken with lye, or rain water employed. * * *

For use on locust trees dilute 1 gallon of emulsion with 2 gallons of soft water.

Pure kerosene and pure petroleum will effectually kill the insects, but may do some damage to the bark of the trees.

Experiments with carbolic emulsion indicate that this preparation is of no value to kill the young larvæ.

POISON BAIT.

Experiments showed that the beetles would feed readily on poisoned bait, such as sugar, sirup, or molasses with some arsenical mixed in, when this was smeared on the trees. Such baits are fatal to the beetles, but the danger of killing honeybees is so great that their use is not recommended in localities where honeybees are kept.

DAMAGE TO CUT WOOD AND DANGER OF INTRODUCING THE INSECT INTO NEW LOCALITIES.

We have determined that after the borers have once entered the wood they may complete their development in the cut and dry branches; they will evidently do so, therefore, in posts or other material manufactured from trees cut between the 1st of May and the middle of September; from this it is plain that locust should not be cut during this period for any purpose except to destroy the borers, or, if it should be necessary to cut it, the tops should be burned and the logs submerged in ponds or streams for a few days before they are shipped or manufactured. This is very important, both to prevent damage to the manufactured material and the introduction of the insect into the far West and other sections of the country which are at present free from it.

SELECTION OF LOCATIONS FOR EXTENSIVE PLANTINGS.

The fact that there are many sections and localities of greater or less extent within the natural home of the locust and its insect enemies where, from some unknown cause, the tree grows to large size and old age without perceptible injury from borers and other insects, suggests the importance of selecting such localities for any proposed extensive operations in the line of artificial planting, or utilization of

natural growth. It will be found, however, that no area of considerable extent, even in such localities, is entirely free from this and other destructive insect enemies, and that certain precautions and well-planned methods of management with reference to the control of the latter will be necessary.

MANAGEMENT OF PLANTATIONS TO PREVENT INJURY.

In the first place it is necessary, in order to provide against future losses from the borer, that a thorough survey be made in May and June, not only of the area to be utilized but of the entire neighborhood for a radius of a mile or more from its borders, for the purpose of locating and destroying scattering trees and groves which are more or less seriously infested or damaged by the borer. It would seem that the control of such large areas, by purchase or under a plan of cooperation between the owners of the land or trees, is one of the most important requisites for success in preventing future losses from the ravages of this and other insects in small as well as large plantations. In fact, it is the writer's opinion that, with this precaution properly and continuously carried out, locust may be successfully protected from the borer in any locality.

In the subsequent management of plantations and of natural forest and sprout growth it is important each year to locate and destroy the worst infested trees for the purpose of killing the borers in the wood, and to conduct the thinning and commercial cutting operations during the period between October of one year and April of the next, in order to destroy the young borers before they enter the wood.

Worthless, scrubby, borer-infested trees should be killed outright by stripping the bark from 4 or 5 feet of the lower stem during August to prevent sprouts and seed production from them, and at the same time to destroy the eggs and young borers. Trees deadened in this manner will usually be so completely killed that not a single root sprout will appear. Therefore this method is of special value in preventing sprout reproduction from inferior individual trees.

SELECTING AND BREEDING BORER-RESISTANT TREES.

The fact that some trees are more or less resistant to attack or injury by the borer, while adjacent ones in the same grove are attacked year after year and seriously damaged, suggests breeding races and varieties of the species which would be permanently resistant.

Breeding experiments have been begun in cooperation with the Bureau of Plant Industry and the Forest Service, but it will require several years to get definite results. In the meantime, however, it is important that seed and cuttings for commercial planting should be selected, as far as possible, from trees which show least damage from

the borer and are otherwise vigorous and healthy. From a well-established principle in the heredity of plants and animals, this practice of propagating from the best examples must certainly yield better results than would follow a disregard of the character of the trees from which seed or root propagations are made.

For reference to literature, and other information not included in this paper, the reader is referred to Part I of this bulletin, pages 1 to 16.

U. S. D. A., B. E. Bul. 58, Part IV. F. I. I., November 10, 1909.

SOME INSECTS INJURIOUS TO FORESTS.

THE SOUTHERN PINE SAWYER.

(*Monohammus titillator* Fab.)

By J. L. Webb, M. S., *Agent and Expert.*

INTRODUCTION.

Monohammus titillator, or the southern pine sawyer, has been known to systematic entomology for over a century. It is somewhat surprising to note, therefore, that scarcely anything is to be found in literature upon the economic importance of this insect, which may truly be said to be one of the most destructive enemies of the crude product of pine forests, especially in the Southern States. Of late years the increasing number of severe storms, so destructive to pine forests in the Southern States, has provided such excellent breeding places for the sawyer in felled trunks and standing stubs that its work is now known to every lumberman in that section of the country as one of the worst injuries to his industry with which he has to contend. The increasing demand by these lumbermen for exact information in regard to the insect rendered necessary a personal investigation of the seasonal history, habits, and facilities for control. To that end the writer spent the months of July and August, 1908, in southern Mississippi, near the town of Baxterville, for the purpose of studying the insect and its habits and conducting a few experiments to determine the best remedy for combating it. Subsequently trips were made to this region in October, 1908, and March, 1909. Investigations were also made, in the latter part of July, 1908, in a district near Kentwood, La., that had been visited by a cyclone, and in a similar district near De Queen, Ark., in October, 1908. The results of these investigations are given in the following pages.

The writer desires to acknowledge, in this connection, the courtesy and kindness of Mr. E. McLennan, of Hattiesburg, Miss., general agent for a company controlling timber land in that vicinity, in furnishing trees on the company's property to be felled for use in seasonal history experiments.

HISTORY.

In 1775 Fabricius published a short description of the adult from a specimen in the British Museum, calling it *Lamia titillator*, and gave its habitat as "Carolina." He also published short descriptions under the same name in 1781 and 1787. Somewhere between 1788 and 1793, the exact date unknown, Linnæus, in the Systema Naturæ, edited by Gmelin, published a short description under the name *Lamia titillator* Fab. In 1792 Fabricius again published a short description of *titillator*, and also published a description of *Lamia dentator*, with "Carolina" as habitat. The latter name has since been placed in synonymy. Olivier, in 1795, published a short description and figure of the adult under the name *Cerambyx titillator* Fab. He gives it the common name "Capricorne chatouilleux" or the "long-horned tickler," and the habitat as "Carolina." At the same time he published a short description and figure of *Cerambyx carolinensis* (common name, the Carolina longhorn), which has since been made a synonym of *titillator*, and gave the habitat as South Carolina. Somewhere between 1795 and 1811, the exact date not being known, the same author published short descriptions of *Lamia titillator* and *Lamia carolinensis*, giving the habitat of the former as "Carolina," and of the latter as South Carolina. In 1805 Beauvois published a short description and figure under the name *Lamia dentator*. In 1835 Serville described the genus Monohammus, and placed *dentator* and *carolinensis* in it, without mentioning *titillator*. Le Conte, in 1854, published a short description and placed *dentator* and *carolinensis* in synonymy. In this connection he says: "Olivier's *carolinensis* very obviously is the female of his *titillator*. * * * It is common in the Southern States."

In 1862 Harris, in his Insects Injurious to Vegetation, published a short description, with a figure and a note on the habits of adults, but stated that the kind of tree the "grub" inhabited was unknown to him. In 1873 Le Conte published a description of *Monohammus minor*, which has since been made a synonym of *titillator*. At the same time he published a short description of *M. titillator*. Of the genus Monohammus, he says: "The species infests pine trees throughout the whole extent of the United States and contiguous northern regions." In the same year Bowditch, under the name *M. dentator*, published short descriptions of the larva, pupa, and adult, and a short note on seasonal history and habits. He found it infesting *Pinus mitis* (*echinata*) in Massachusetts. In 1885 Horn published a short description under the name *M. titillator* and placed the names *carolinensis*, *dentator*, and *minor* in synonymy. He gave the distribution as from Canada to Washington Territory and south to Florida. In 1899 Hopkins published a short note on the occurrence

of this species resting upon pitch and scrub pine trees at Tibbs Run, near Dellslow, W. Va. In the same year Chittenden published a a short account of the destructive habits of the species of the genus Monohammus. J. B. Smith, in his Insects of New Jersey, published the same year, mentions this species as occurring throughout the State on pine in June and July. In 1906 Felt, in his Insects Affecting Park and Woodland Trees, under the name *M. titillator* (common name, tickler), published a very short description, saying further that it was met with in very small numbers [in New York] in 1901 on both white pine and hard pine.

DISTRIBUTION.

The records of the Bureau of Entomology indicate that this species is to be found over the whole eastern half of the United States, from Maine to Texas. As stated in the historical notes, Doctor Horn gave the distribution as from Canada to Washington Territory, and south to Florida, but I have not been able to verify his statement as to the northern and western limits of distribution.

HOST PLANTS.

So far as known, this species attacks only pine trees, not favoring any one species of pine, but apparently attacking all species of pine trees within its range of distribution.

CONDITION OF TREES ATTACKED.

Only felled or injured trees are attacked by this species. So far as known, healthy standing trees are never in any danger whatever from this source.

INJURY TO PINE FORESTS BY STORMS.

In September, 1906, a high wind accompanied by rain, blowing steadily for two or three days, uprooted a vast amount of pine timber in the southern part of Mississippi.

In May, 1907, near Tuscaloosa, Ala., a storm occurred which felled about 800,000 feet of pine timber.

On April 24, 1908, a cyclone of huge proportions passed through Mississippi and Louisiana, tearing down a swath of timber from 1 to 2 miles wide (fig. 13). The cyclone passed through some of the finest pine forests in these States, thus bringing down or breaking off many millions of feet of timber. It is quite probable that the same storm did damage in Arkansas. At any rate, two storms occurred in Arkansas, one in April and one in May, 1908, both of which were very destructive to pine timber. During the fall and winter of 1908 two or three more storms occurred in the same State which doubtless contributed to the destruction of the pine forests.

INJURY TO STORM-FELLED TIMBER BY THE SOUTHERN PINE SAWYER.

Practically all timber felled by the storm of September, 1906, became infested by the sawyer. When the writer reached Baxterville, Miss., July 6, 1908, the broods had all matured and emerged from these trees. In this vicinity, where most of his investigations were carried on, from 75 to 90 per cent of the trees felled by the storm of April 24, 1908, were infested by the sawyer. Adults were at that time actively engaged in laying eggs in the uninfested trunks

FIG. 13.—The effect of the storm of April 24, 1908. (From a photograph taken near Baxterville, Miss.)

and stubs. This continued for the balance of the summer, so that it is safe to say that a very small percentage of the pine timber injured by this storm escaped infestation. The damage to each log infested is the work of the larvæ or grubs which mine in and through the sapwood, and even penetrate the heartwood, making large unsightly holes which cause the lumber made from this portion of the log to be thrown into the very lowest grade, known to the lumbermen as "No. 2 common."

PECUNIARY LOSS.

Approximately 25 per cent of the lumber in each log infested by the sawyer is seriously damaged. The pecuniary loss may therefore be computed as follows: Lumber undamaged by insects was worth, in 1908, $19 a thousand feet b. m. at the mill in southern Mississippi. When infested by the sawyer the 25 per cent damaged was reduced in value to $7.50 a thousand.

It is estimated that in the storm of September, 1908, 2,000,000,000 feet of timber were blown down. In the 1907 storm, in Alabama, 800,000 feet were blown down, and in the storm of April 24, 1908, which passed through two or three States, 180,000,000 feet were blown down. This gives us 2,180,800,000 feet of timber blown down by these three storms. Practically all of this storm-felled timber was damaged by the sawyer.

As stated above, 25 per cent of each log damaged is reduced from $19 a thousand feet to $7.50 a thousand feet; therefore we may consider that 25 per cent of the whole, or 545,200,000 feet b. m. was reduced from $19 a thousand to $7.50 a thousand. At $19 a a thousand this amount of timber would be worth $10,358,800. At $7.50 it would be worth $4,089,000. The difference between these two sums is $6,269,800. Therefore, if this timber had been used, or could have been used before the sapwood decayed, the last figure given would represent the total loss chargeable to the sawyer.

CHARACTER OF THE INSECT.

Adult.—The adult (fig. 14) is an elongate beetle varying from 16^{mm} to 31.5^{mm} in length and from 5 to 10^{mm} in width. The color is a mottled gray and brown. In the male the horns, or antennæ, are very long, often being two or three times the length of the beetle. In the female they are much shorter than in the male, but are still somewhat longer than the body.

Egg.—The egg (fig. 15) is elongate-oval, approximately 4^{mm} long, by 1.5^{mm} in diameter at the middle. The color is opaque white. There are two distinct coverings, which correspond to the outer and inner shells of the egg of a fowl. The outer is known as the chorion (fig. 15, *a*, *d*), and the inner as the amnion (fig. 15, *b*). At one end is found a depression or little round hole, which is known as the micropyle (fig. 15, *c*). Under a high-power microscope the chorion is seen to be very prettily sculptured on its outer surface (fig. 15, *e*).

Larva.—The larva (fig. 16) is an elongate, footless, white grub with powerful jaws or mandibles for boring through the wood. The size varies considerably in different individuals and according to age. The largest at maturity have been found to measure slightly over 60^{mm} in length and 9^{mm} in breadth at the broadest point (the pro-

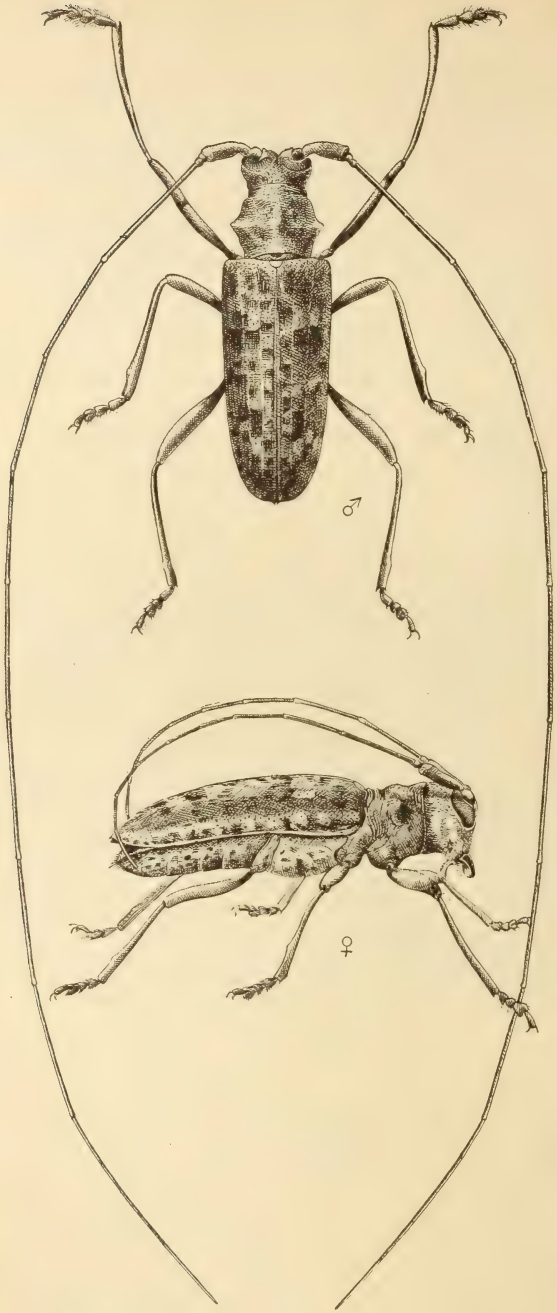

FIG. 14.—The pine sawyer (*Monohammus titillator*): ♂, Male; ♀, female. Enlarged about one-third. (Original.)

thorax). Larvæ which develop into the smaller sized adults are, of course, much smaller than this at maturity. The body is divided into 14 well-marked segments. The first is the head. The following three constitute the thorax, the first being the prothorax, the second the mesothorax, and the third the metathorax. The following 9 segments constitute the abdomen, and are designated as the 1st, 2d, 3d, etc., abdominal segments. The last segment is called the anal segment. The head (fig. 16, *a*) is considerably longer than broad, and is capable of being deeply retracted into the thorax. The prothorax, upon the anterior part of the upper or dorsal surface, is smooth and shining, but the posterior part has an opaque leathery appearance. This opaque surface is dotted over by small shining spots more or less longitudinally elongate in shape. The mesothorax is smooth upon the upper or dorsal surface, but on the lower or ventral surface is found a double transverse row of fine fleshy granules. On the extreme anterior portion of the side of this segment is found a transverse, oval, brown spot. This is the first spiracle or breathing pore. On the

FIG. 15.—The pine sawyer. Egg, greatly enlarged: *a*, Chorion; *b*, amnion; *c*, micropyle; *e*, same, highly magnified; *d*, sculpture of chorion. (Original.)

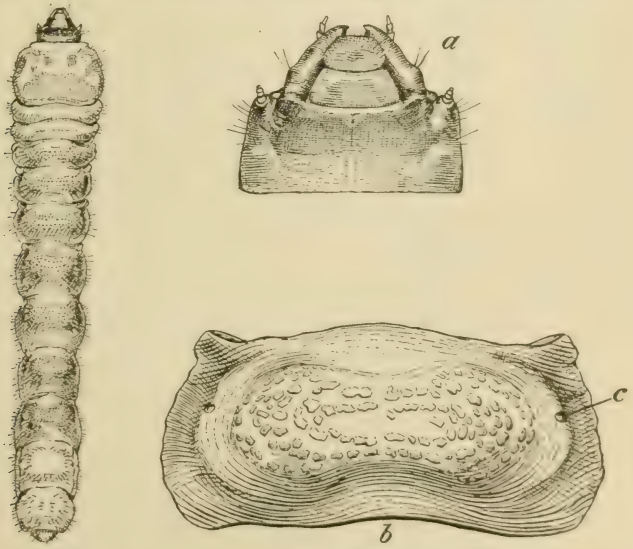

FIG. 16.—The pine sawyer. Larva, slightly enlarged: *a*, Fore part of head; *b*, second abdominal segment; *c*, abdominal spiracle. *a*, *b*, Greatly enlarged. (Original.)

metathorax a double transverse row of granules occurs, both on the dorsal and on the ventral surface, but there is no spiracle upon this segment. On the first 7 abdominal segments there are 4 rows of granules on the dorsal surface (fig. 16, *b*), and 2 on the ventral. The

last 2 segments are free from granules. On the anterior half of the side of each abdominal segment except the last, a spiracle (fig. 16, *c*) similar to that on the mesothorax, except that it is much smaller, is to be found. In mature larvæ each abdominal segment bears a longitudinal fold on each side, known as the pleural fold. On immature larvæ the pleural folds on the first 2 abdominal segments are so obscure as to be scarcely noticeable. The anal fold is quite hairy and bears the anal opening. Numerous hairs occur upon each segment of the entire body.

Pupa.—The pupa (fig. 17) shows the form in some degree of both the larva and the adult. The number of segments is the same as in the larva; the first abdominal segment, however, is not visible upon the under side of the body. The head is of the same general shape as that of the adult, but is bent forward and under, so that the mouth-parts point directly back toward the posterior end of the body. Several bristles are found upon the anterior part of the head. The antennæ are well developed and are coiled on the under side of the elytra, or wing covers, which extend from the mesothorax in a posterior lateral direction, the tips being directly underneath the body and attaining the fourth abdominal segment. The elytra thus lie between the body and the first two pairs of legs. The third pair of legs is between the body and the elytra. The wings are flattened against the under side of the elytra, each one projecting slightly beyond the outer side margin of the elytron, under which it lies. The elytra are attached to the mesothorax and the wings to the metathorax.

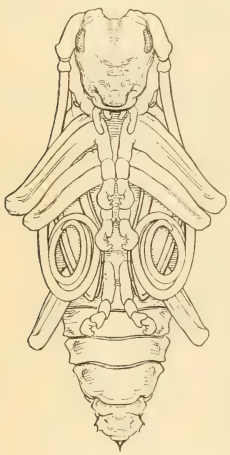

FIG. 17.—The pine sawyer: Pupa. About twice natural size. (Original.)

There is a large fleshy tubercle at each side of the prothorax. The legs are folded underneath the body. The first pair is borne by the prothorax, the second by the mesothorax, and the third by the metathorax. The mesothorax bears a spiracle in the same position as that of the larva, and the first 5 abdominal segments bear spiracles; the rest apparently do not. Upon the dorsal surface all segments of the thorax and abdomen bear bristles. The ventral surface of all abdominal segments, except the last, is smooth. The last abdominal segment, which occupies the extreme posterior end of the body, has a peculiar triangular shape. One of the points of the triangle is prolonged upward into a sharp, chitinized spine. The two lower points of the triangle are armed with several chitinized bristles. The anal segment occurs directly beneath the last abdominal segment, and is inclosed on three sides by the latter. A strongly marked sexual difference is to be found between the anal segment of the male and that

of the female. In the male this segment shows merely the anal opening. In the female two globular tubercles are borne side by side on this segment.

SEASONAL HISTORY.

There are four stages in the life of the sawyer, first, the egg (fig. 15); second, the larva (fig. 16); third, the pupa (fig. 17); fourth, the adult (fig. 14).

In southern Mississippi the egg-laying period lasts from about the first of March to the middle of October. In some cases eggs may be laid earlier or later than the dates given, but the main activity in egg-laying will be found to be comprised within this period. The young larvæ hatch from the eggs in about five days after the eggs are deposited.[a]

The length of time from the hatching of the young larva to the time of maturity and change to the pupa appears to vary considerably in different individuals. The comparative periods of time spent in the larval and pupal stages are not known. However, it is probable that while the larval period may last for several months the pupal period is not longer than two or three weeks. The length of time occupied in passing from the egg to the adult stage varies greatly in different individuals. It appears that normally there is one generation a year, with a partial second generation. Thus, on August 12, 1908, the writer found larvæ, pupæ, and emergence holes in the trunk of a tree which had been felled by storm April 24, 1908. The fact that the tree was felled on this date makes it certain that the eggs of the sawyer were deposited subsequently. This gives us a period of less than four months for the development from the egg to the emerged adult, in some individuals. Returning to the same tree October 6, 1908, more emergence holes were found, but there were still plenty of larvæ in the trunk. Also, scattering emergence holes were common at this date in other trees felled by the storm of April 24, 1908, which were also abundantly infested with larvæ. On March 19, 1909, the writer again visited the tree just mentioned, and found a good many larvæ and one pupa still in the log. Thus it is seen what a great variation in the length of time taken for development there may be among different individuals in the same log. The case of the sawyer in the Southern States appears to be somewhat analogous to that of certain species of Lepidoptera, a few adults of which emerge in the fall, while the greater number of the pupæ go through the winter before changing

[a] This statement is based upon observations made during the hottest part of the summer. Possibly eggs laid in the spring or fall might not hatch so quickly, as there would be less heat at those periods.

to the adult. In the case of the sawyer, however, the winter is passed in the larval stage and not the pupal stage. In November, 1908, Mr. R. W. Van Horn found emergence holes of the sawyer in trees felled the previous spring near Virginia Beach, Va., thus showing that the same conditions prevail there.

Among the larvæ which pass the winter in the logs, those which are farthest advanced in development are, of course, the first to go through the changes to the adult, and to emerge in the spring. It is probable that this emergence begins about March 1. At the time the writer was in southern Mississippi, March 18–20, 1909, many adults had already emerged and others were ready to emerge. Females were actively engaged in laying eggs at this time.

Just how long it takes for all the overwintered larvæ, which have not already done so, to go through the changes to the adult stage and emerge is not known, but it is probable that this will be accomplished at least by June 1.

From the last of July, 1908, to the first of February, 1909, the writer had trap trees felled at stated intervals, for the purpose of getting seasonal history notes. The following tabulation shows the net results of these experiments:

Seasonal history records of the pine sawyer from pine trees felled from July, 1908, to February, 1909.

Hopk. U. S. No.	Date of felling.	First eggs noted.	Condition on March 18–19, 1909.
	1908.	1908.	
5873	July 29	Aug. 6	Larvæ and pupæ in wood. A good many adults have emerged.
5874	29	6	Larvæ, pupæ, and young adults in wood. A good many adults have emerged.
5879	Aug. 10	13	Larvæ and pupæ in wood. No emergence holes noted.
5880	10	13	Do.
5885	20	.....	Larvæ and pupæ plentiful in wood. No emergence holes noted.
5886	20	.....	Larvæ and pupæ common in wood. Three adults have emerged.
5893	31	.....	Larvæ and pupæ in wood. Several adults have emerged.
5894	31	.....	Larvæ and pupæ in wood very scarce. One young adult (quite small). Two adults have emerged.
5895	Sept. 11	.....	Larvæ and pupæ in wood. No emergence holes.
5896	11	.....	Larvæ and pupæ rather scarce in wood. A few adults have emerged. A few larvæ between bark and wood, scoring the wood.
5897	28	Oct. 7	Larvæ and pupæ in wood. One larva found between bark and wood, which crawled back into its hole in the wood. One adult has emerged.
5898	28	7	Larvæ, pupæ, and young adults in wood. Several adults have emerged.
5914	Oct. 15	.....	Larvæ, some of which have not entered wood, others in wood with exit burrow excavated nearly to surface. No pupæ or emergence holes.
5915	15	.....	Larvæ, some between bark and wood, scoring the wood, not having made entrance holes into wood. Others in wood with emergence gallery excavated nearly to surface. No pupæ or emergence holes noted.
5912	Nov. 3	.....	A few inconspicuous egg pits evidently made last fall. Two half-grown larvæ, one of which had commenced to mine into the wood. The other had not commenced to do so.
5913	3	.....	Two or three egg pits, evidently made last fall, but no larvæ or eggs found.
5910	Dec. 8	.....	Many egg pits. Eggs and young larvæ in some cases, in others the conditions seem to have become unfit by reason of the excavations of other insects.
5911	8	.....	Many egg pits. Eggs and young larvæ under bark.
	1909.	1909.	
5908	Jan. 7	.....	A few egg pits of Monohammus with eggs. One small larva found.
5909	7	.....	Scattering egg pits over the log. Eggs and larvæ apparently one or two weeks old.
5906	Feb. 6	Mar. 18	A few egg pits, both in trunk and stump. Eggs under bark, but none found that have hatched. March 20, female digging egg pit.
5907	6	18	A few egg pits with eggs under the bark. One larva found apparently just hatching. March 20, six beetles, three males and three females, observed on this log, the females excavating egg pits, two males fighting and the other male hanging on to a female.

HABITS.

Preparatory to laying the eggs, the female digs with her mandibles quite a conspicuous egg pit in the bark (figs. 18, *a*, and 21, *c*). This pit is more or less funnel shaped, though sometimes it is merely a transverse slit, and reaches as far as the outermost layer of soft, sappy bark. The female, while digging the egg pit, is generally accompanied by the male, who clasps the posterior end of her body with his forelegs, and frequently fertilizes her while she is digging the pit. In one instance where the operation was noted, the female did not discontinue digging while copulation took place. Many combats take

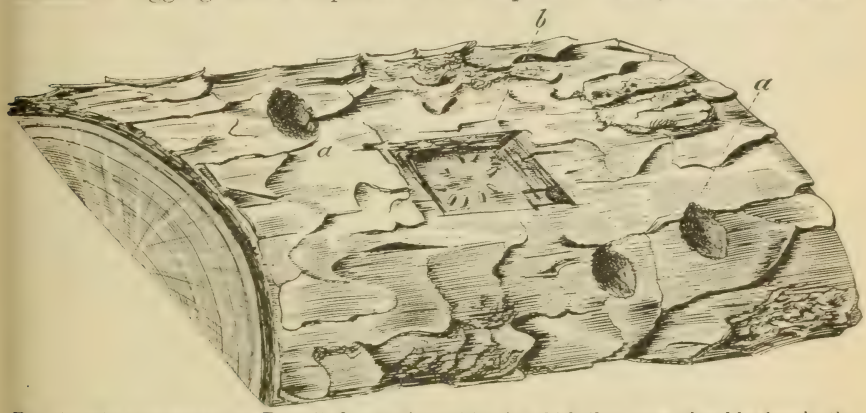

FIG. 18.—The pine sawyer: *a*, Egg pit; *b*, eggs in position in which they were placed by female, the outer bark being removed. About one-half natural size. (Original.)

place between males for the possession of a female during oviposition. The ovipositor is thrust into the egg pit and in between the soft, sappy bark and the first layer of outer hard bark, and the eggs are deposited in a circle around the bottom of the egg pit, the egg (or the end of the egg nearest the pit) being placed from one-eighth to one-quarter of an inch away from the egg pit (see fig. 18, *b*). As many as nine eggs have been found deposited through a single pit opening.

In about five days these eggs hatch, and the small larvæ issuing therefrom begin feeding upon the soft inner bark, and soon work their way through it, but do not enter the wood until they have attained considerable growth. During this period they make irregular galleries through the inner bark just next to the wood, deriving their entire sustenance from the bark and making no marks or cuttings upon the wood. In from eighteen to thirty-two days after hatching the larvæ mine into the sapwood (fig. 19). A few days previous to this they are to be found cutting rather broad, irregular paths upon the surface of the sapwood with their mandibles (fig. 19, *d*). This process is called "scoring." After making the entrance into the wood the larvæ come out again to feed upon the inner bark, evidently

retiring into their holes to rest and for protection from their enemies. The chips cut in excavating the hole in the wood, as well as the excrement, are packed between the bark and wood and are not thrown

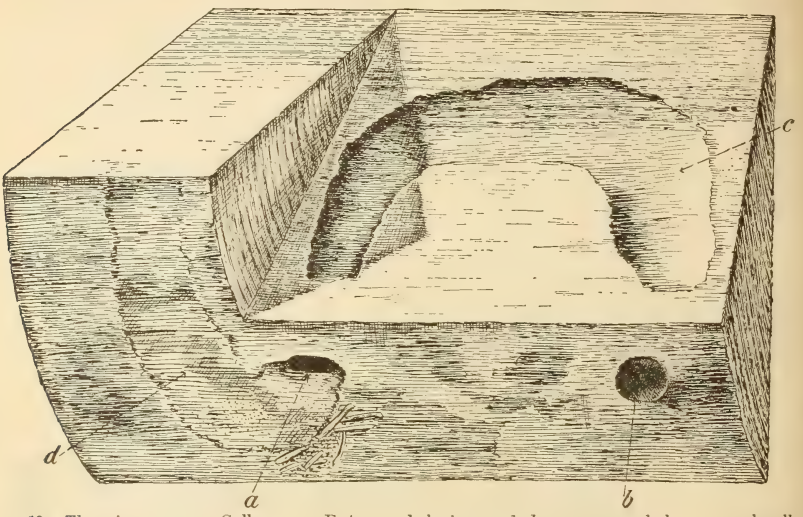

FIG. 19.—The pine sawyer. Gallery: *a*, Entrance hole in wood; *b*, emergence hole; *c*, pupal cell; *d*, surface scored by larva before entering wood. About natural size. (Original.)

out upon the ground, as appears to be the case with some other species. In moving about from the entrance of the hole in the wood to the place where food is obtained, very distinct channels are made through this mass of refuse (fig. 21). This habit appears to continue until the larva is ready to pupate, when, of course, it retires to the pupal chamber (fig. 19, *c*) already constructed, where it remains until the adult stage is reached. Previous to pupation the larva extends the gallery in the sapwood until the heartwood is reached. As a general thing the gallery here turns in a longitudinal direction for 2 or 3 inches, then turns again toward the surface, giving the entire gallery a U-shaped appearance (fig. 19). Sometimes the bottom of the "U" extends a short distance into the heartwood, but as a usual thing it merely reaches it. In the bottom of the "U" is to be found the pupal cell. The gallery is here greatly widened and enlarged in order to accommodate the insect while going through its

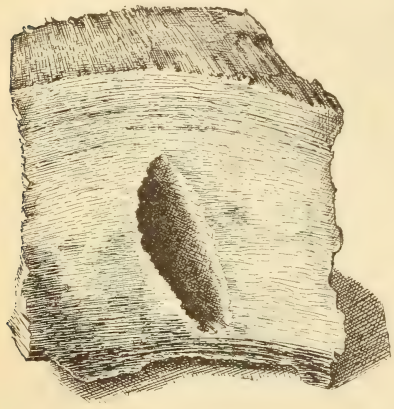

FIG. 20.—The pine sawyer: Cross section of pupal cell. About natural size. (Original.)

transformations (figs. 19, *c*, 20). The unfinished arm of the "U" is usually extended by the larva to within about one-quarter of an inch of the surface of the wood. When the larva pupates, the head of the pupa is turned toward the end of the chamber. When the pupa changes to the adult, the beetle extends the chamber to the surface of the wood and through the bark, if the bark is still upon the tree or

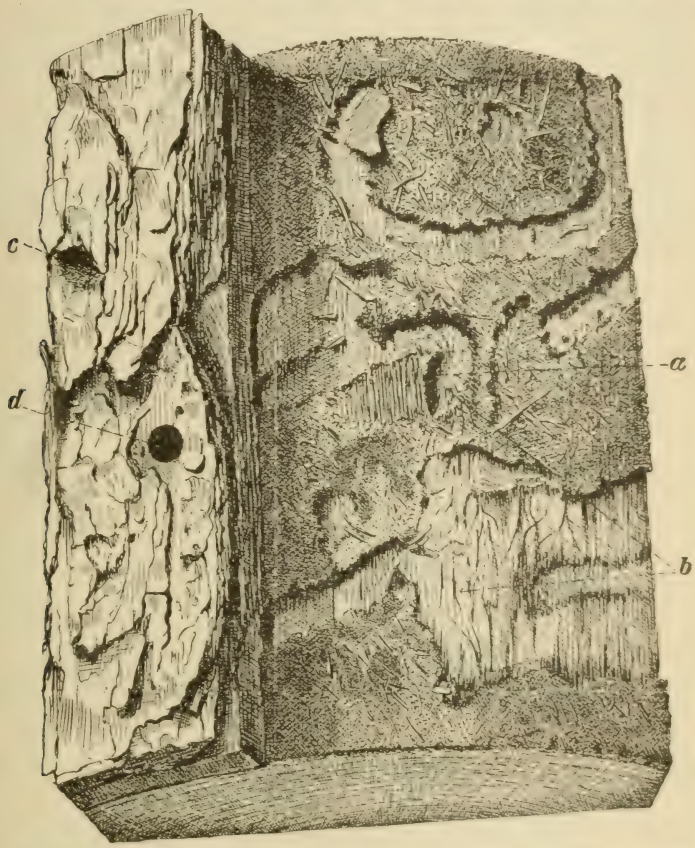

FIG. 21.—The pine sawyer: Section of pine showing, at right, mass of borings and refuse packed under bark (bark removed) by the larvæ and channels made through the mass by the larvæ. *a*, Entrance hole of larva in wood; *b*, scored surface of wood; *c*, egg pit; *d*, emergence hole. About one-half natural size. (Original.)

log, boring a perfectly round exit hole usually about three-eighths of an inch in diameter (figs. 19, 21, 22), thereby escaping to propagate the species in another tree or trees.

NATURAL ENEMIES.

Monohammus titillator is preyed upon by larvæ of the coleopterous family Trogositidæ; by the larva of an elaterid beetle of the genus Alaus, and by a species of Bracon which has been determined as new to science. None of these, however, has been powerful enough, so

far, to appreciably thin the ranks of Monohammus. Following is the description, by Mr. H. L. Viereck, of the species of Bracon mentioned above:

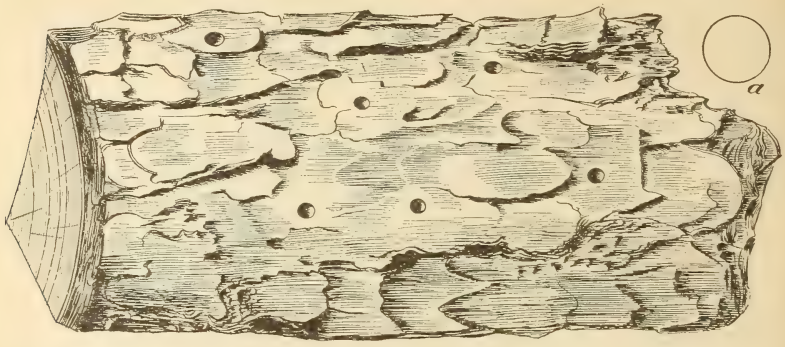

FIG. 22.—The pine sawyer: Emergence holes of young adults in bark. *a*, Natural size of emergence holes. (Original.)

BRACON (MELANOBRACON) WEBBI N. SP.[a]

Compared with *ulmicola* [b] this species differs as follows: Second dorsal abdominal segment without a triangular elevated area but with shallow, almost oblique impressions as diagrammatically represented in figure 23.

FIG. 23.—*Bracon* (*Melanobracon*) *webbi:* Dorsum of second abdominal segment. Greatly enlarged. (Original.)

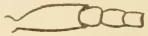

FIG. 24.—*Bracon* (*Melanobracon*) *webbi:* First four antennal joints. Greatly enlarged. (Original.)

Female: Length, 11mm, exclusive of ovipositor, which is 6mm; antennæ 69-jointed; proportions and relation of first four joints approximately as in figure 24; joints 4 to 55 subequal, becoming wider than long; joints 55 to 69 becoming longer than wide, the apical joint conical. Petiole of first discoidal cell about as long as second and third joints of antenna combined. Second dorsal abdominal segment perfectly smooth.

Type.—No. 12585, U. S. National Museum.

Type locality, Baxterville, Miss., March 19, 1909.

Hopk. U. S. No. 5896*a*; reared by Mr. J. L. Webb, of the Bureau of Entomology.

REMEDIES.

Fire.—During the logging operations upon the storm-felled timber near Baxterville, Miss., in 1908, the felled timber was burned over with the object of destroying the broods of the sawyer. Subsequent examinations of this burned-over area disclosed the fact that a very small percentage of the larvæ had succumbed to the heat. *This method is, therefore, not to be recommended.*

Scoring.—Several experiments were tried to determine the efficiency of "scoring," or removing a strip of bark along the upper surface of a log. In some instances salt was sprinkled along the

[a] By H. L. Viereck, Agent and Expert, Bureau of Entomology.

[b] 1906, Trans. Am. Ent. Soc., pp. 176–177.

scored surface, and in others the strip was covered with brush, these having been recommended locally as remedies. In not a single instance was the scoring, either with or without salt, found to deter the larvæ in the slightest degree. *This method is not recommended.*

Placing logs in water.—Investigation of the method of destroying the larvæ in infested logs by placing the logs in water was made at Lumberton, Miss., where logs from the storm-felled trees were placed in the mill pond. The water killed all the larvæ in the log, both between the bark and wood and in the wood itself. *This method is to be recommended wherever practicable.*

Barking the logs.—Barking the logs is effective up to the time the larvæ enter the wood, and for a short time thereafter—perhaps a week. As stated elsewhere, the first part of the life of the larva is spent between the bark and the wood, during which the larva feeds upon the soft inner bark. It is absolutely impossible for the larva to live for the first month of its existence without this soft inner bark to feed upon. Therefore, if the bark be removed from the log during this period all larvæ between the bark and wood will be destroyed. As stated elsewhere, the larvæ continue to feed upon the inner bark for several days at least, after first entering the wood. The writer determined by experiment that the barking of the log during the first few days after the larvæ have entered the wood was effective in destroying the larvæ, by cutting off their food supply. At this period the larvæ have not gone deeply into the wood, so that there would still be a saving if the barking were done at this time. Where this method is practiced as a remedy, it should be done within forty days after the eggs are laid. If trees are felled between March 1 and October 15, egg laying will probably commence at once after the trees are down.

An important point to be taken into consideration in this connection is whether or not logs and trees barked to destroy the sawyer can be taken to the mill before the sapwood decays from lying on the ground. As the greater part of the injury by the sawyer is confined to the sapwood, there will obviously be little or no saving in barking logs which can not be used before the sapwood is destroyed by decay.

The writer realizes, also, that in some cases barking may not be profitable for other reasons. The local conditions in regard to labor are often far from satisfactory. And it may be quite impossible to assemble enough laborers to bark all the trees felled by a heavy storm in time to save them from injury by the sawyer. It is also true that in cyclone-felled timber the trunks are often so piled up and entangled that it would be necessary to saw them into logs and separate them before they could be barked. However, taking all these points into consideration, the writer feels that in the

majority of instances a great saving can be accomplished if the matter is promptly taken in hand, and as many trunks as possible barked before or shortly after the larvæ enter the wood. In each case the holder of storm-felled timber must decide for himself. If the cost of barking the felled trunks is low enough to give a fair profit on the material saved from injury, it is a simple proposition of business economy. In any case the matter should be given careful consideration before all effort to prevent loss from the ravages of the sawyer is abandoned.

SUMMARY OF REMEDIES.

If possible saw all storm-felled trunks into logs and place the logs in water before the larvæ enter the wood, or within forty days after the eggs are laid. If it is impossible to place the logs in water, they should be barked within forty days after the first egg pits are observed in the bark.

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SOME INSECTS INJURIOUS TO FORESTS.

INSECT DEPREDATIONS IN NORTH AMERICAN FORESTS AND PRACTICAL METHODS OF PREVENTION AND CONTROL.

By A. D. Hopkins, Ph. D.,
In Charge of Forest Insect Investigations.

INTRODUCTION.

It is the purpose of this part of the bulletin to give a summary of facts, conclusions, and estimates relating to the forest-insect problem as applied to North American conditions and to call attention to its importance in the future management of private, state, and national forests.

The matter is presented in as brief and concise a form as possible, in order that the information may be readily available to the general reader, as well as to the forester and student, and references are made to publications in which more detailed accounts may be found.

The statements and conclusions relating to the insects and their work and to methods for their control are based almost entirely on investigations and observations by the writer and by assistants in the Bureau of Entomology working under his direction, carried on in all of the principal forest areas of the United States. The historical data have been gathered from the publications listed on pages 96–97. The estimates of the amount and value of standing timber killed by insects and of the forest products destroyed and reduced in value through insect injuries to the crude and seasoned products are based on our published results of investigations (pp. 97–100), on unpublished notes, on technical and practical knowledge of the subject, and on the published forest statistics relating to the amount and value of timber, fire losses, etc. (pp. 100–101).

INSECT DEPREDATIONS IN NORTH AMERICAN FORESTS.

CHARACTER AND EXTENT OF DEPREDATIONS.

The records of notable depredations by insects on the timber supply of Europe during the past four hundred years, on that of the

United States during the past century, and especially those that have come under the observation of the writer and assistants engaged in forest insect investigations during the past eighteen years, furnish conclusive evidence that this class of enemies has been, and is now, an important factor in the destruction and waste of forest resources.

Insects Cause the Death of Trees.

It has been conclusively demonstrated that certain species of insects are the direct or primary cause of the death of forest trees of all ages, and that from time to time they multiply to such an alarming extent that their depredations assume the character of a destructive invasion, which results in the death of a large percentage of the best timber over thousands of square miles.

There are many species of barkbeetles which prefer to attack matured and healthy trees, and there are many examples of whole forests of century-old trees having perished from the girdling effect of the mines of the beetles, which are extended in all directions through the inner living bark on the main trunks of the trees. Indeed, we find among these bark-boring beetles the most destructive insect enemies of North American forests. Some notable examples of the depredations of these barkbeetles are given below.

The southern pine beetle.—In 1890–1892 a destructive invasion of the southern pine beetle (*Dendroctonus frontalis* Zimm.) extended from the western border of West Virginia through Maryland and Virginia into the District of Columbia, northward into southern Pennsylvania, and southward into North Carolina. In this area, aggregating over 75,000 square miles, a very large percentage of the mature and small trees of the various species of pine and spruce was killed by this beetle. In many places in West Virginia and Virginia nearly all the pine trees of all sizes on thousands of acres were killed, while shade and ornamental trees within the same area suffered the same as those in the forest. Since 1902 this barkbeetle has been more or less active in the Southern States from Virginia to Texas, and in some localities and during certain years it has killed a large amount of timber. Records of extensive destruction of timber in the Southern States are found dating back to the early part of the nineteenth century (Wilson, 1831). This species may be considered one of the most dangerous insect enemies of southeastern conifers and, therefore, a constant menace to the pine forests of the Southern States. (Hopkins, 1899*b*, 1903*b*, 1909*b*.)

The eastern spruce beetle.—During the period between 1818 and 1900 there were several outbreaks of the eastern spruce beetle (*Dendroctonus piceaperda* Hopk.) in the spruce forests of New York, New England, and southeastern Canada (Peck, 1876, 1878; Hough, 1882; Packard, 1890; Pinchot, 1899, p. 74; Hopkins, 1901*a*, 1909*b*).

This species caused the death of a very large percentage of the mature spruce over an area of thousands of square miles. In the aggregate many billions of feet of the best timber were destroyed. The larger areas of this dead timber furnished fuel for devastating forest fires, with the result that in most cases there was a total loss.

The Engelmann spruce beetle.—Another barkbeetle (*Dendroctonus engelmanni* Hopk.), similar in habits to *piceaperda*, has from time to time during the past fifty years caused widespread devastations in the Rocky Mountains region to forests of Engelmann spruce, in some sections killing from 75 to 90 per cent of the timber of merchantable size. (Hopkins, 1908*a*, p. 161; 1909*b*, pp. 126–132.)

The Black Hills beetle.—One of the most striking examples of the destructive powers of an insect enemy of forest trees is found in the Black Hills National Forest of South Dakota, where during the past ten years a large percentage of the merchantable timber of the entire forest has been killed by the Black Hills beetle (*Dendroctonus ponderosæ* Hopk.). It is estimated that more than a billion feet of timber have been destroyed in this forest as the direct result of the work of this beetle. This destructive enemy of the western pine is distributed throughout the forests of the middle and southern Rocky Mountains region, where, within recent years, it has been found that in areas of greater or less extent from 10 to 80 per cent of the trees have been killed by it. (Hopkins, 1902*a*, 1903*b*, 1905*b*, 1908*a*, and 1909*b*, pp. 90–101.)

The mountain pine beetle and the western pine beetle.—The sugar pine, silver pine, western yellow pine, and lodgepole pine of the region north of Colorado and Utah, westward to the Cascades, and southward through the Sierra Nevadas are attacked by the mountain pine beetle (*Dendroctonus monticolæ* Hopk.) and the western pine beetle (*Dendroctonus brevicomis* Lec.), and, as a direct consequence, billions of feet of the timber have died. In one locality in northeastern Oregon it is estimated that 90 to 95 per cent of the timber in a dense stand of lodgepole pine covering an area of 100,000 acres has been killed within the past three years by the mountain pine beetle. Throughout the sugar-pine districts of Oregon and California, as the result of attacks by this same destructive barkbeetle, a considerable percentage of the largest and best trees is dead. (Webb, 1906; Hopkins, 1908*a*, 1909*b*, pp. 80–90.)

The Douglas fir beetle.—The Douglas fir throughout the region of the Rocky Mountains from southern New Mexico to British Columbia has suffered severely from the ravages of the Douglas fir beetle (*Dendroctonus pseudotsugæ* Hopk.), with the result that a large percentage of dead timber is found, much of which will be a total loss. (Hopkins, 1909*b*, pp. 106–114.)

Three other species of beetles, having destructive habits similar to those above mentioned, depredate on the pines of New Mexico

and Arizona, and still another has contributed greatly to the destruction of the larch throughout the northeastern United States and southeastern Canada. (Hopkins, 1909*b*, pp. 49, 53, and 77.)

The hickory barkbeetle.—Within the past ten years the hickory barkbeetle (*Scolytus quadrispinosus* Say) has caused the destruction of an enormous amount of hickory timber throughout the northern tier of States from Wisconsin to Vermont and southward through the eastern Atlantic States and into the Southern States as far as central Georgia. (Hopkins, 1904*b*, pp. 314–317.)

The larch worm.—There are also many examples of widespread depredations chargeable to insects which defoliate the trees, thus contributing to their death. Notable among these are the depredations by the larch worm (*Nematus erichsonii* Hartig), which, during several extensive outbreaks since 1880, has killed from 50 to 100 per cent of the mature larch over vast areas in the northeastern United States and southeastern Canada. It is evident that the amount of merchantable-sized timber that has died as the result of defoliation by this insect will aggregate many billions of feet. (Packard, 1890, pp. 879–890; Pinchot, 1899; Hopkins, 1908*a*.)

Insect Injuries to the Wood of Living Trees.

It has been determined that insects of a certain class attack the wood and bark of living timber and that, while they do not contribute materially to the death of the trees or give much external evidence of their presence, they produce wounds in the bark and wormhole and pinhole defects in the wood which result in a depreciation in commercial value amounting to from 5 to 50 per cent. These defects in the wood are not detected until after the trees have been felled and the logs transported to the mill and converted into lumber. Thus to the actual damage to the lumber is added the expense of logging and manufacture of the defective, low-grade material, much of which must be discarded as worthless culls. (Hopkins, 1894*a*, 1894*b*, 1904*b*, 1905*a*, 1906*b*.)

The oak timber worm.—One of the most destructive of the class of depredators just mentioned is the oak timber worm (*Eupsalis minuta* Dru.). It enters the wood of the trunks of living trees through wounds in the bark and at the base of broken or dead branches and extends its "pinhole" burrows in all directions through the solid heartwood. The losses occasioned by this insect in the hardwood forests of the eastern United States are enormous and usually affect the wood of the finest examples of old trees. (Hopkins, 1894*a*, 1904*b*.)

The chestnut timber worm.—The chestnut throughout its range is damaged in a like manner by the chestnut timber worm (*Lymexylon sericeum* Harr,). Practically every tree of merchantable size is

more or less affected, and a large percentage is so seriously damaged that the product is reduced to that of the lowest grade. It is estimated that the reduction in value of the average lumber product at any given time is not far from 30 per cent, thus involving extensive waste and an increased drain on the forest to supply the requirements for clear lumber. This insect also attacks the oaks, and especially the red oak, the older trees of which are often as seriously damaged as are the chestnut. (Hopkins, 1894*a*, 1904*b*.)

Carpenter worms.—The oaks, especially the white oak and the red oak, are seriously damaged by carpenter worms of the genus Prionoxystus. The holes made by these insects through the heartwood of the best part of the trunks are sometimes 1.5 inches in diameter one way by 0.75 inch the other, thus causing serious damage to the wood. These, with other large wood-boring beetle larvæ, sometimes infest the top part of the trunk and the larger branches of oak trees, where their continued work results first in the dead and so-called "stag-horn" top and subsequently in broken, decayed, and worthless trunks. (Hopkins, 1894*a*, 1904*b*.)

Ambrosia beetles.—One of the commonest defects in white oak, rock oak, beech, whitewood or yellow poplar, elm, etc., is that known to the lumber trade as "grease spots," "patch worm," and "black holes." This defect is caused by one of the timber beetles or ambrosia beetles, *Corthylus columbianus* Hopk., which makes successive attacks in the living healthy sapwood from the time the trees are 20 or 30 years old until they reach the maximum age. Thus the black-hole and stained-wood defect is scattered all through the wood of the best part of the trunks of the trees. The average reduction in value of otherwise best-grade lumber amounts, in many localities, to from 25 to 75 per cent. The defect is commonly found in oak and elm furniture and in interior hardwood finish in dwellings and other buildings. (Hopkins, 1893*g*, 1894*b*, 1904*b*.)

The locust borer.—The locust, as is well known, suffers to such an extent from the ravages of the locust borer (*Cyllene robiniæ* Forst.) that in many localities the trees are rendered worthless for commercial purposes or they are reduced in value below the point of profitable growth as a forest tree, otherwise this would be one of the most profitable trees in the natural forest or artificial plantation and would contribute greatly to an increased timber supply. (Hopkins, 1906*b*, 1907*a*, 1907*c*.)

Turpentine beetles and turpentine borers.—While the softwood trees, or conifers, suffer far less than the hardwoods from the class of enemies which cause defects in the living timber there are a few notable examples of serious damage. There is a common trouble affecting the various species of pine throughout the country known as basal wounds or basal fire wounds. It has been found that a large

percentage of this injury to the pine in the States north and west of the Gulf States and in the Middle and South Atlantic States is caused by the red turpentine beetle (*Dendroctonus valens* Lec.) and in the Southern States by the black turpentine beetle (*Dendroctonus terebrans* Oliv.). These beetles attack the healthy living bark at and toward the base of the trunks of medium to large trees and kill areas varying in size from 1 to 10 square feet. These dead areas are subsequently burned off by surface fires and are then generally referred to as fire-wounds. The further damage to the exposed wood by successive fires, decay, and insects often results in a total loss of the best portion of the tree, or a reduction in value of the lower section of the trunk of from 10 to 50 per cent. (Hopkins, 1904*a*, 1909*b*.) These and similar wounds in the bark of trees, including those caused by lightning and by the uncovering and exposure of the wood in turpentining, offer favorable conditions for the attack of the turpentine borer (*Buprestis apricans* Hbst.), the work of which, together with that of two or three others with similar habits, is very extensive, and causes losses amounting to from 10 to 50 per cent of the value of the wood of the best part of the trees thus affected. (Hopkins 1904*a*.)

The white pine weevil.—The abnormal development of white pine trees as the result of succesive attacks on the terminals of the saplings and young trees by the white pine weevil (*Pissodes strobi* Peck) is an element of loss of considerable importance, especially in mixed stands and in open pure stands of this timber. The value of such trees is reduced from 20 to 50 per cent below those of normal development, and there is an additional loss from the effect of their spreading branches or crowns in the suppression or crowding out of trees which would otherwise occupy the space thus usurped. (Hopkins, 1906*c*, 1907*d*.)

There are many other examples of insects which damage the wood and bark of living trees, but those mentioned should be sufficient to demonstrate the importance of insects in this relation.

Insect Injuries to the Wood of Dying and Dead Trees.

Timber dying from insect attack and other causes, including fire, disease, storms, etc., is attacked by certain wood-boring insects which extend their burrows through the sound sapwood and heartwood, and thus contribute to the rapid deterioration and decay of a commodity which otherwise would be available commercially during periods of from one to twenty years or more after the death of the trees, depending on the species of trees and on the character of the product desired. This loss often amounts to from 25 to 100 per cent during the period in which the dead timber would otherwise be almost as valuable as if living. (Hopkins, 1894*a*, 1901*d*, 1904*a*, 1905*a*; Webb, 1909.)

CONIFEROUS TREES.

Sawyers.—One of the most striking examples of the destruction or deterioration of the wood of dying and dead timber, familiar to all lumbermen, is the injury to fire-killed and storm-felled pine, fir, spruce, etc., caused by boring larvæ known as "sawyers." These borers hatch from eggs deposited by the adult beetles in the bark of the dying trees, and after feeding on the inner bark for a time they enter the solid wood and extend their large burrows deep into the heartwood. Fire-killed white pine is especially liable to this injury, and is often so seriously damaged within three or four months during the warm season as to reduce the value of the timber 30 to 50 per cent. The shortleaf, loblolly, and longleaf pines of the Southern States are damaged to a somewhat less extent, but instances are known in which more than one billion feet of storm-felled timber within limited areas were reduced in value 25 to 35 per cent within three months after the storm. (Webb, 1909.) The fire-killed and insect-killed sugar pine, silver pine, and yellow pine of the western forests are also damaged in a similar manner and the value of the product greatly reduced within a few months after the trees die. The aggregate losses from this secondary source in the coniferous forests of the entire country contribute largely to the annual waste of millions of dollars' worth of forest products which otherwise might be utilized. (Hopkins, 1905*a*, p. 385; Webb, 1909.)

Ambrosia beetles.—Wood-boring insects of another class, known as timber beetles or ambrosia beetles, cause pinhole defects, principally in the sapwood, although some of them extend their burrows into the heartwood. These insects make their attack in the early stage of the declining or dying of the tree, or before the sapwood has materially changed from the normal healthy condition, and often in such numbers as to perforate every square inch of wood. Thus the wood is not only rendered defective on account of the presence of pinholes, but the holes give entrance to a wood-staining fungus which causes a rapid discoloration and produces still further deterioration of the product.

The sapwood of trees dying from the attack of other insects or from fire, storm, or other causes is often reduced in value 50 per cent or more, and in some cases the value of the heartwood is reduced in a like manner from 5 to 10 per cent. (Hopkins, 1894*a*, 1895*c*, 1898*b*, 1904*a*, 1905*a*.)

Pinhole borers in cypress.—An example of the destructive work of insects which attack dying and dead trees is found in the cypress in the Gulf States, where these trees are deadened by the lumbermen and left standing several months, or until the timber is sufficiently dry to be floated. Upon investigation it was found that trees dead-

ened at certain seasons of the year were attacked by the ambrosia beetles or pinhole borers, and that in some cases millions of feet of timber had been reduced 10 to 25 per cent or more in value. (Hopkins, 1907*b*.)

HARDWOOD TREES.

Roundheaded borers, timber worms, and ambrosia beetles.—The principal damage to dying and dead hardwood trees is caused by certain roundheaded wood-borers (Cerambycidæ) with habits similar to the sawyer, by the timber worms mentioned as damaging living timber, and by ambrosia beetles having habits similar to those that attack the sapwood and heartwood of conifers. All of the hardwoods suffer more or less, but the greatest damage is done to the wood of hickory, ash, oak, and chestnut, which are often reduced in value 10 to 25 per cent or more within the period in which it would otherwise remain sound and available for commercial purposes. (Hopkins, 1894*a*, 1904*a*, 1905*a*.)

INSECT INJURIES TO FOREST PRODUCTS.

Damage is caused by various species of insects which are attracted by the varying conditions prevailing at different stages during the process of utilizing the forest resources, from the time the trees are felled until the logs are converted into the crude and finished product and until the latter reaches the final consumer, or even after it is placed in the finished article or structure. As a result, additional drains are made on the timber to meet the demand for the higher grades of lumber and for other supplies to replace those injured or destroyed. From the writer's personal investigations of this subject in different sections of the country it is evident that the damage to forest products of various kinds from this cause is far more extensive than is generally recognized. This loss differs from that resulting from insect damage to standing timber in that it represents more directly a loss of money invested in material and labor. (Hopkins, 1894*a*, 1903*c*, 1904*a*, 1905*a*.)

CRUDE PRODUCTS.

Roundheaded borers, timber worms, and ambrosia beetles.—Round timber with the bark on, such as poles, posts, mine props, sawlogs, etc., is subject to serious damage by the same class of insects as those mentioned under injury to the wood of dying and dead trees. The damage is especially severe when material is handled in such a manner as to offer favorable conditions for attack (Hopkins, 1905*a*), as when the logs are left in the woods on skidways or in mill yards for a month or more after they have been cut from the living trees. Under such conditions there is often a reduction in value of from 5 to 30 per cent or more, due to wormhole and pinhole defects caused by

roundheaded and flatheaded wood-borers and timber beetles. Frequently the insects continue the work in the unseasoned and even dry lumber cut from logs which had been previously infested. They also continue to work in mine props after they have been placed in the mine, and in logs and other material used for the construction of cabins, rustic houses, etc., and in round timbers generally.

The products from saplings, such as hickory hoop-poles and like material, are often seriously injured or rendered worthless by roundheaded and flatheaded borers and wood-boring beetles, sometimes resulting in a loss of from 50 to 100 per cent of the merchantable product. (Hopkins, 1905*a*.)

Stave and shingle bolts left in moist, shady places in the woods or in close piles during the summer months are often attacked by ambrosia beetles and timber beetles. The value of the product is often reduced, as a consequence, from 10 to 50 per cent or more. (Hopkins, 1894*a*, 1905*a*.)

Handle and wagon stock in the rough is especially liable to injury by ambrosia beetles and roundheaded borers. Hickory and ash bolts from which the bark is not removed are almost certain to be greatly damaged if the logs and bolts cut from living trees during the winter and spring are held over for a few weeks after the middle of March or first of April. (Hopkins, 1905*a*.)

Pulpwood, and cordwood for fuel and other purposes, cut during the winter and spring and left in the woods for a few weeks or months or in close piles after the beginning of the warm weather, are sometimes riddled with wormholes or converted into sawdust borings, causing a loss of from 10 to 100 per cent. One example reported from near Munising, Mich., represents a loss of $5,000 from injury to spruce and fir pulpwood cut in the winter and kept in piles over summer.

MANUFACTURED UNSEASONED PRODUCTS.

Ambrosia beetles and other wood borers.—Freshly sawed hardwood placed in close piles during warm, damp weather during the period from June to September is often seriously injured by ambrosia beetles. Heavy 2-inch to 3-inch stuff is also liable to attack by the same insects, even in loose piles. An example of this was found in some thousands of feet of mahogany lumber of the highest grade, which had been sawed from imported round logs and piled with lumber sticks between the tiers of plank. Native species of ambrosia beetles, principally *Pterocyclon mali* Fitch, had entered the wood to such an extent as to have reduced the value 50 per cent or more within a few weeks. Oak, poplar, gum, and similar woods often suffer severely from this class of injury, causing losses varying from 5 to 50 per cent. (Hopkins, 1905*a*.)

Lumber and square timbers of both soft and hard woods with the bark left on the edges are frequently damaged by flatheaded and roundheaded wood borers, which hatch from eggs deposited in the bark before or after the lumber is sawed. There are examples of losses from this character of injury amounting to from 20 to 50 per cent or more.

Telegraph and telephone poles, posts, mine props, etc., are frequently injured before they are set in the ground, especially if the bark remains on them during a few weeks after the middle of March.

SEASONED PRODUCTS IN YARDS AND STOREHOUSES.

Powder-post beetles.—Hardwood lumber of all kinds, rough handles, wagon stock, etc., made partially or entirely of sapwood, are often reduced in value from 10 to 90 per cent by a class of insects known as powder-post beetles. The sapwood of hickory, ash, and oak is most liable to attack. The reported losses from this source during the past five or six years indicate that there has been an average reduction in values of from 5 to 10 per cent or more. (Hopkins, 1903*c*, 1905*a*.)

Old hemlock and oak tanbark is often so badly damaged by various insects which infest dead and dry bark that in some tanyards as much as 50 to 75 per cent of the bark that is over three years old is destroyed. In one tannery in West Virginia it is estimated that more than $30,000 worth of hemlock bark was thus destroyed. (Hopkins, 1905*a*.)

FINISHED PRODUCTS.

The greatest loss of finished hardwood products, such as handle, wagon, carriage, and machinery stock, is caused by powder-post beetles. This is especially true of hickory and ash handles and like products in the large and small storehouses of the country, including the vast amount of material held in storage for the army and navy. When material of this kind is once attacked it is usually worthless for the purposes indicated, and therefore must be replaced with new material. In some cases losses have amounted to from 10 to 50 per cent, and it is estimated that the average losses have been as much as 10 per cent on nearly all sapwood material that has been in storage more than one year. (Hopkins, 1903*c*, 1905*a*.)

UTILIZED PRODUCTS.

Powder-post beetles, white ants, and other wood-boring insects.—The finished woodwork in implements, machinery, wagons, furniture, and the inside finish in private and public buildings are often seriously damaged by powder-post beetles, thus requiring increased demands for new material. (Hopkins, 1903*c*, 1905*a*.)

, Construction timbers and other woodwork in new and old buildings are often so seriously damaged by powder-post beetles, white ants, and other wood-boring insects that the affected material has to be removed and replaced by new, or the entire structure torn down and rebuilt. (Hopkins, 1905*a*.)

Construction timbers in bridges and like structures, railroad ties, telephone and telegraph poles, mine props, fence posts, etc., are sometimes seriously injured by wood-boring larvæ, termites, black ants, carpenter bees, and powder-post beetles, and sometimes reduced in efficiency from 10 to 100 per cent.

INSECTS IN THEIR RELATION TO THE REDUCTION OF FUTURE SUPPLIES OF TIMBER.

Insects not only reduce future supplies by killing the mature trees and destroying the wood of timber that is inaccessible for utilization, but through injuries inflicted upon trees during the flowering, fruiting, germinating, seedling, and sapling periods of early growth they prevent normal reproduction and development. (Hopkins, 1904*a*, 1906*c*.)

INTERRELATIONS OF FOREST INSECTS AND FOREST FIRES.

Investigations conducted by the writer and assistants in all sections of the country during the past ten years indicate to them quite conclusively that the average percentage of loss of merchantable timber in the forests of the entire country to be charged to insects during a five or ten year period is infinitely greater than most people realize. (Hopkins, 1906*a*, pp. 4–5, 1908*b*, p. 345, 1909*b*, pp. 5, 24; Forbes, 1909, pp. 51–52.)

Losses from forest insects.—The writer estimates (p. 70) that for a ten-year period the average amount of timber in the forests of the entire country killed and reduced in value by insects would represent an average loss of $62,500,000 annually.[a]

It has been estimated (Hopkins, 1905*b*, p. 5; 1908*a*, p. 162) that the Black Hills beetle killed approximately 1,000,000,000 feet b. m. of timber during a period of ten years, which at $2.50 per thousand would amount to an average of $250,000 annually. This is merely one example of very destructive depredations by a single species of barkbeetle in a single national forest.[b] (See also p. 70.)

Prof. Lawrence Bruner, state entomologist of Nebraska, at a meeting of the American Association of Economic Entomologists, held at

[a] *Losses from forest fires.*—It has been estimated that "on the average, since 1870, forest fires have yearly cost $50,000,000 in timber." (Cleveland, T., jr., 1909, p. 3.)

[b] It has been estimated that the losses of timber from forest fires on all of the National Forests of the United States from 1905 to 1908, inclusive, average only $165,062 annually. (Cleveland, T., jr., 1908, p. 541.)

Baltimore, Md., in December, 1908, spoke as follows: "I can agree with Doctor Hopkins that the insects are far more important in destroying our forests than fires." (Bruner, 1909, p. 53.)

Insect-killed timber as fuel for fires.—It has often happened that after insects have killed the timber over extensive areas the standing and fallen dead trees furnished fuel for great forest fires which have not only destroyed or charred the dead timber but killed the living timber and reproduction and swept on into adjacent areas of healthy timber. Indeed, abundant evidence has been found during recent investigations to indicate that some of the vast denuded areas in the Rocky Mountains and other sections of the country are primarily due to widespread devastation by insects, and that subsequent fires destroyed the timber and prevented reproduction. (Hopkins, 1906*a*.)

It is also evident that a considerable percentage of dead timber, and especially that found in coniferous forest regions, which has generally been believed to have been fire-killed is a result of primary attack by insects. This has been demonstrated in many cases by the pitch-marked galleries of the destructive barkbeetles on the surface of the wood of the old dead trees which had escaped subsequent fires.

Fire-killed timber injured by insects.—It is true that a vast amount of timber has been killed outright or has died as the direct result of forest fires, but in almost every case observed insects have contributed to a greater or less extent to the death of recently fire-injured trees which might otherwise have recovered, and especially to the rapid deterioration of the wood of a large percentage of the injured and killed trees. It is evident that in some cases fire-scorched and fire-killed timber has contributed to the multiplication of one or more of the insect enemies destructive to living timber, and thus the injury started by the fire may have resulted in a destructive outbreak of beetles. However, it is evident that this has happened only when the destructive beetle was already present in abnormal numbers in the forest surrounding the fire-swept area. Therefore, *it is believed that injuries by fire are not as a rule an important factor in contributing to subsequent depredations by barkbeetles.* Such fires, however, contribute to the multiplication of the insects which depredate on the bark and wood of dying and dead trees, so that in forested areas where fires are frequent the damage to the wood of such trees is more severe, and fewer injured trees recover on account of the abundance of secondary barkbeetle enemies which do not, as a rule, attack and kill living timber.

Destruction of insects by fire.—There is another important feature in the relation of insects and fire, in which the fire contributes to the destruction of the principal barkbeetle enemies of the living timber. This happens when the fire burns the timber while it is infested, thus effectually destroying the broods of the insects. It is perfectly plain that the dying and dead foliage of the beetle-infested trees and the

dead bark on the trunks would contribute to the spreading of crown fires and thus the bark on the entire infested trunks would be sufficiently scorched to kill the insects. Therefore, complete fire control may easily contribute to more extended depredations by insects on the living timber, thus increasing, rather than diminishing, the need for insect control. However, the setting of fires or permitting them to burn for the purpose of combating insects should never be undertaken or permitted.

Durability of insect-killed timber.—Some of the matured larch trees which evidently died as a result of defoliation by the larch worm between 1881 and 1885, and which had escaped subsequent depredations by fire and wood-boring insects, were found by the writer in 1908 to be standing and sound enough to be utilized for railroad ties and many other purposes. Under similar conditions the heartwood of red spruce and white pine in the East, of Engelmann spruce in the Rocky Mountains, and of Douglas fir in the Northwest coast region have been found by the writer to be sound enough for profitable utilization for pulp wood, lumber, fuel, and other purposes from twenty to thirty years after it had been killed by insects or fire. Thus it is shown that timber killed by insects and fire would be available for utilization for many years were it not for injuries through the secondary attacks of wood-boring insects and the destruction of insect-killed timber by forest fires.

INTERRELATION OF FOREST INSECTS AND FOREST FUNGI.

Decay following injury by insects.—It is well known that the burrows in the bark and wood of living and dead trees and in the crude and finished products often contribute to the entrance of bark and wood decaying fungi. Deterioration and decay are thus far more rapid than would otherwise be possible. It is also known that trees injured and dying from primary attack by parasitic fungi are attractive to certain insects which breed in the bark and wood of sickly and dying trees, and that certain other complicated troubles affecting forest trees are the result of an intimate interrelation and interdependence of insects and fungi. There can be no doubt, however, that certain species and groups of both insects and fungi are independently capable of attacking and killing perfectly vigorous and healthy trees.

SUMMARY AND ESTIMATES RELATING TO CHARACTER AND EXTENT OF INSECT DAMAGE.

The killing of trees by insects; the damage by them to the wood of living, dying, and dead timber; the destruction of insect-killed timber by subsequent forest fires; the damage to fire-killed timber by insects; and the damage from decay resulting from insect injuries to the wood, have all been more or less continuous for centuries and are still going on in the forest and woodland areas of this country.

While these depredations are not always evident or important in all forests or localities, yet almost every year, somewhere in the forests of the country, there are widespread depredations.

In every forest and woodland there is an ever present but inconspicuous army of insects which require the bark, wood, foliage, and seeds of the various tree species for their breeding places or food. Thus, the accumulated but inconspicuous injuries wrought during the period required for the growth of a tree to commercial size go far toward reducing the average annual increment below the point of profitable investments.

The accumulated damage to crude, finished, and utilized products reduces the profits of the manufacturer, increases the price of the higher grades to the consumer, and results in an increased drain on the natural resources.

In any attempt to estimate in *dollars* or *feet, board measure*, the extent of losses or waste of timber supplies caused by insects there are many conflicting factors which contribute to the difficulty of arriving at accurate conclusions. The published information concerning the amount in board feet of standing timber in the country is admittedly only an estimate, as are also the published data relating to average stumpage value. The published statistics relating to the amount and value of forest products are of course more accurate, but until more complete data can be furnished by the forest experts on the various complicated phases of forest statistics, any figures given by the forest entomologist relating to the value of timber and commercial products destroyed or reduced in value by insects must be considered on the same basis as the other estimates, and as the best that can be presented on available evidence.

Standing timber killed and damaged by insects.—When we consider the amount of standing merchantable timber killed by insects and the amount of standing timber, living, dying, and dead, which has been reduced in quantity and value through their agency during a ten-year period, we would estimate that such timber represents an equivalent of more than 10 per cent of the quantity and stumpage value of the total stand of merchantable timber in the United States at any given time.[a] A certain percentage of such timber is a total

[a] The estimate of the area and stand of the present forests of the United States, as given in Circular 166 of the Forest Service, page 6, is two trillion five hundred billion feet (2,500,000,000,000) board measure. The average stumpage value has been given as $2.50 per one thousand feet b. m., making a total value of the standing merchantable timber of $6,250,000,000. Ten per cent of this amount would be $625,000,000, as the amount to be charged to insects for a 10-year period, or an average of $62,500,000 annually. As an example, it has been estimated that over 1,000,000,000 feet b. m. of timber was killed by the Black Hills beetle in the Black Hills National Forest within a period of ten years. This, at $2.50 per one thousand feet stumpage, would be an average of $250,000 annually in a single forest of 1,294,440 acres.

loss because of the impossibility of utilization; but in some cases a greater or less percentage can be, and in some cases is, utilized within the period in which it is of sufficient value to yield a profitable return on the cost of logging and manufacture, although its value is greatly reduced.

Reduction in the Nation's wealth.—When we consider the forest resources both in merchantable timber and young growth as an important asset of the Nation's wealth: as representing a given value to the people for direct utilization; as a cover to the soil for protection of the land from erosion; as protection of headwater streams and of game; and as contributing to the æsthetic value of health and pleasure resorts, it would be difficult indeed to estimate the amount or percentage of loss of timber or the reduction in the land values, in each case, chargeable to insects. It is plain, however, that in the aggregate it is considerably greater than when estimated on stumpage values alone.

Reduction in cash revenue.—When we consider the problem from the standpoint of direct utilization we can estimate the annual loss on a basis of mill values; but here again we meet with complications, since much of the damaged material is left standing or is discarded in the woods or at the mill without measurement. Therefore we are left to judge from our observations and knowledge of the general conditions as regards dead and damaged timber found in the forests of the country, and the information from lumbermen in different sections, as to the percentage of loss from defective timber. On this basis we can estimate that the amount of insect-killed and damaged timber left in the woods, plus the reduction in value of that utilized, to be charged to insects is not far from an equivalent of 10 per cent of the value of the annual output of forest products of all kinds, in the rough. The total value of the forest products of the United States in 1907 is given as $1,280,000,000; the losses from insect depredations would therefore represent an annual loss in a cash value of more than $100,000,000. (Hopkins, 1895*c*, 1904*a*.)

Reduction in value of finished and commercial products.—When we consider the aggregate loss to the manufacturers of the finished products, to the trade, and to the consumer from insect injuries to the wood, it is evident that it amounts to many millions of dollars in addition to the estimated loss of crude products, or at least 3 per cent of the mill value.

METHODS OF PREVENTION AND CONTROL.

The results of extensive investigations and of practical applications of the knowledge gained during recent years have demonstrated that some of the most destructive insect enemies of American forests and of the manufactured and utilized products can be controlled, and

serious damage prevented, with little or no ultimate cost over that involved in forest management and business methods. (Hopkins, 1904*b*, 1905*a*, 1908*a*, 1909*b*.)

There are, of course, certain insects and certain injuries which, under present conditions and available information, can not be controlled or prevented, but it is very evident that if the information now available through the publications of the Department of Agriculture and through direct correspondence with its experts is properly utilized in the future it would result in the prevention of at least 30 per cent of the estimated annual waste of forest resources that has been caused by insects within recent years, and thus contribute greatly to the conservation of forest resources.

GENERAL PRINCIPLES OF CONTROL.

The ordinary spraying and similar methods employed in dealing with fruit and shade tree insects are, of course, not available for practical application in the case of forest trees. But there are other and less expensive methods of accomplishing the desired results.

In all efforts to control an outbreak or prevent excessive loss from forest insects it should be remembered that as a rule it is useless to attempt the complete extermination of a given insect enemy of a forest tree or forest product. Experience has demonstrated that it is only necessary to reduce and weaken its forces 75 per cent or more. It can not then continue an aggressive attack, but must occupy a defensive position against its own enemies until conditions resulting from avoidable negligence and mismanagement by the owners of the forests and manufacturers of forest products favor its again becoming destructive. Forest insects can thus be easily kept under control by good management.

The desired control or prevention of loss can often be brought about by the adoption or adjustment of those requisite details in forest management and in lumbering and manufacturing operations, storing, transportation, and utilization of the products which at the least expenditure will cause the necessary reduction of the injurious insects and establish unfavorable conditions for their future multiplication or continuance of destructive work.

It is, however, of the utmost importance that any adjustment or modification in management or business methods should be based on expert technical knowledge or advice relating to the species, habits, life history, and natural enemies of the insects involved and the essential features of the methods for their control. This should be supplemented by expert knowledge or advice on the principles of technical and applied forestry in the proper management, care, and utilization of the forest and its resources, and still further supplemented by practical knowledge and experience relating to local con-

ditions and facilities favorable and unfavorable for success in practical applications according to the recommended method or policy of control.

As has been shown, the mature or merchantable timber is the most susceptible to injury or death from the ravages of insects. Therefore, considered from the standpoint of insect control and the prevention of one of the greatest items of loss, it is important that such matured timber should be utilized before it begins to deteriorate, or before it reaches the stage of unprofitable growth.

For the greatest success in dealing with forest insects, it must be recognized that there are certain features in the habits and seasonal history of each species which differ to a greater or less extent from those of all other species, even of the same genus; that there are certain features in the characteristics of the various species of trees which differ from those of all other species; and that as a rule it is the technical knowledge of these peculiar features or characteristics of the trees and their enemies which furnishes the clew to successful methods of control.

There are also many peculiar features in the prevailing conditions in different localities, some of them favorable, others unfavorable, for the practical application according to a given method, so that while certain general advice may apply in a broad sense and be available for utilization by the practical man, whether owner, manager, or forester, without further advice, it is often necessary to diagnose a given case before specific expert advice can be given as to the exact cause and the most effective method or policy to be adopted, just as a physician must diagnose a case of illness or injury before prescribing the required treatment for his patient.

Therefore, in a consideration of the problem as to how far the waste of forest resources caused by insects can be prevented and how far the damaged timber can be utilized, we will attempt to give only general statements based on the results of our observations relating to some of the principal kinds of loss discussed in the first part of this paper, namely, by insects which (1) kill the trees, (2) cause injuries to the wood of living timber, (3) reduce future supplies, and (4) cause injuries to the manufactured products. In addition, we will consider the utilization of natural enemies of injurious insects, the utilization of damaged timber, and the present conditions and opportunities for success in the general control of forest insects.

CONTROL OF BARKBEETLES WHICH KILL TREES.

The barkbeetles which kill trees attack the bark on the trunk and destroy the life of the tree by extending their burrows or galleries in all directions through the inner living bark. The broods of young grubs or larvæ develop within the inner bark, on which they feed.

Those of some species develop to the adult stage within the inner bark and are exposed when the bark is removed, while those of other species transform to the adults in the outer corky bark and the larvæ are not exposed when the bark is removed. Some species have two or more generations in a season or annually, while others have but one, and in a few species it requires two years for a single generation to develop. (Hopkins, 1909*b*.)

The barkbeetles of the genus Dendroctonus represent the most destructive enemies of the principal coniferous tree species of American forests, and at the same time are among the easiest of control. The general requisites for success are embodied in the following rules:

(*a*) Give prompt attention to the first evidence of a destructive outbreak, as indicated by an abnormal percentage of yellow or red topped dying trees, and especially when such trees occur in groups of ten or more or cover large areas; (*b*) secure authentic determination of the particular species of insect responsible for the trouble; and (*c*) take prompt action toward its control according to specific expert advice, published or otherwise, on the best method for the destruction of the necessary 75 per cent or more of the insects in the infested trees.

Some of the methods to be adopted to meet the requirements of various local conditions are as follows:

(1) Utilize the infested timber and burn the slabs during the period in which the broods of the destructive beetles are in the immature stages or before the developed broods emerge from the bark; or

(2) Fell the infested trees and remove the bark from the main trunk and burn the bark if necessary;[a] or

(3) Remove the infested bark from the standing timber and burn the bark when necessary;[a] or

(4) Immerse the unbarked logs in ponds, lakes, or streams, where the bark will remain soaked long enough to kill the insects; or

(5) Remove the unbarked logs or products to a locality where there are no trees liable to attack within a radius of 20 miles or more.

Maintaining Control of Barkbeetles.

Future trouble of a serious nature from barkbeetles which kill trees can be prevented within a given forest or area of greater or less extent if an insect-control policy is adopted in connection with, or independent of, a fire-control policy by which groups of dying trees will receive similar prompt attention as that required for the prevention or control of forest fires.

In state and national forests.—In all forest reserves in which there is an organized force of rangers and fire wardens or patrols each

[a] If the broods develop to adults in the outer bark, it must be burned; if they develop in the inner bark and are exposed when the bark is removed, burning is not necessary. As a rule the burning of the tops to destroy the insects is not necessary.

officer should be furnished with instructions for the location of beetle-infested trees, and with equipment and directions for taking the necessary action whenever the conditions demand or warrant it.

In private forests.—Private forests should receive the same attention as public forests, but this is often far more difficult on account of intervening forests, where the owners either can not or will not give the matter the required attention. While it may be advisable to have some laws to govern the treatment of timber infested with a dangerous pest, when the owner refuses to take any action such a law should apply only to the more extreme cases or as a last resort on authoritative advice. It is probable that in most cases legislation will not be necessary, and more ultimate good will result without than with strict laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that, when necessary, his neighbors will render assistance, as is done in the case of a forest fire.

Inaccessible areas.—There are yet large inaccessible areas in the East and West where it is not practicable or possible at present to control the depredations by these beetles and which must therefore be left to the same natural adjustment that has been going on in all forests from their beginning. While under such natural control much of the older matured timber will be lost it will usually be replaced by young growth, either of the same species of trees or of a different species, so that under normal conditions the forest will be perpetuated; but under exceptional conditions and combinations of detrimental influences, such as secondary insect enemies, fire, drought, etc., extensive areas may be completely denuded, never to be reforested under natural conditions. Therefore it will evidently not be very long before it will pay to adopt insect-control policies even in the areas that are inaccessible for profitable lumbering.

Examples of Successful Control of Barkbeetles.

We have a sufficient number of examples of successful control of depredations by the destructive barkbeetles to demonstrate the practicability of the advice based on the results of recent entomological investigations.

Control of the eastern spruce beetle.—The control of an alarming outbreak of the eastern spruce beetle (*Dendroctonus piceaperda* Hopk.) in northeastern Maine in 1900 and 1901 was effected by the concentration of regular logging operations into the areas of infested timber and placing the logs in lakes and streams and driving them to the mills on the Androscoggin River. Thus, with little or no additional expense, there was a saving to one firm, according to its estimates, of more than $100,000.

Control of the Black Hills beetle.—An extensive outbreak of the Black Hills beetle (*Dendroctonus ponderosæ* Hopk.) in the vicinity of Colorado Springs, Colo., in 1905–6, which was threatening the living pine timber of the entire section, was brought under control through the efforts of the private owners of forests and those of forest officials in the adjoining National Forests. It was accomplished by cutting and barking about 1,000 beetle-infested and beetle-killed pine trees. The cost of the operations was largely, if not entirely, covered by the utilized felled timber, although there was considerable unnecessary expense involved through the felling and barking of trees from which the beetles had emerged and from the unnecessary burning of the bark and tops.

The successful control of another serious outbreak of the Black Hills beetle, in 1906, on an extensive private estate in southern Colorado, was effected through the efforts of the owners, who had some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. These operations were so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the value of utilizable timber was evidently more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented.

The most striking example of success relates to a large estate near Idaho Springs, Colo., and in the adjoining Pike National Forest. In May, 1907, it was found that some 63,000 feet of standing timber on the estate was infested by the Black Hills beetle, and the owner was advised by the Bureau of Entomology that unless the ravages were checked at once the beetle would kill the timber not only on this estate but that on the adjoining estates and National Forest, and that therefore radical action should be taken according to the recommendations and detailed instructions given relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the broods of beetles from swarming from the infested trees and extending their ravages. In December, 1907, another examination of the timber was made, and it was found that instead of 65,000 feet of timber in the old infestation there was nearly four times as much timber involved in the new, or over 250,000 feet. The owner was again notified of the serious character of the outbreak, and further suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before May, 1908, it would result in the protection of the remaining living timber. Immediate steps were then taken by the owners to carry out the original

recommendations. An expert in locating infested timber, working under instructions from this Bureau, gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy the necessary number of beetles; he also marked infested timber on an adjoining estate and on the National Forest. Five months later, in May, 1908, this expert reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that the marked trees on the adjoining estate and National Forest had been cut and barked. In November, 1908, another inspection of the forest on the estate and surrounding area was made by the expert, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled, and at no expense to the owner of the timber involved; in fact a very satisfactory price was realized, resulting in a net profit, I understand, of over $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate, November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, and over a mile from where the large clumps of infested trees were cut. With the exception of those three trees, there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had been cut and barked. On the Pike National Forest, contiguous to the first mentioned estate, where you will remember I marked some clumps of infested trees, no new infestation was found, not one tree.

This most gratifying result demonstrated two important things: One, that an extensive outbreak by the most destructive barkbeetle enemy of the pine timber of the central Rocky Mountain forests, involving in this case more than 1,000 infested trees, can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details of the recommendations and expert advice, based on the results of scientific research, can be successfully applied by a manager of a private forest or by the rangers of national and state forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and essentially the same recommendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, the outbreak was allowed to extend beyond practical control, and in conse-

quence a large percentage of the timber of the entire National Forest has been killed. There were, then, no forcible examples of the practical value of such recommendations based on scientific research, and no other argument was effective in arousing public interest in the threatening character of the outbreak or confidence in scientific advice or methods of control. Now we have several examples demonstrating the practicability of forest-insect control in America which should lead to confidence in the results of scientific research as a basis for success in practical application.

Control of the hickory barkbeetle.—The complete control of the hickory barkbeetle (*Scolytus quadrispinosus* Say), which threatened the total destruction of the hickory trees on Belle Isle Park, at Detroit, Mich., in 1903, was effected by felling and removing the infested trees and converting them into merchantable products, all without cost to the park commission. (Hopkins, 1904*b*.)

CONTROL OF INSECTS WHICH CAUSE DEFECTS IN LIVING TIMBER.

The class of insects which causes defects in the wood of living timber can be controlled to a greater or less extent, depending upon local conditions, and a large percentage of the losses prevented through the adoption of certain requisite details in forest management. Of these the following are especially important:

(1) The utilization of all of the defective and infested timber that will pay expenses for manufacture into merchantable products, such as lumber, cordwood, etc.

(2) The burning of infested timber and waste material not available for use, including dead standing and fallen timber, to remove the breeding places of insects like the oak timber worm and the chestnut timber worm, which go from the dead to the living timber.

(3) The prevention of wounds of any kind in the bark of living trees.

(4) The prevention of future losses by the practice of improved forestry methods which will eliminate favorable conditions for injury and contribute to a perpetual supply of vigorous, healthy timber to be utilized before it passes the stage of profitable increment.

PREVENTION OF INJURY TO DYING AND DEAD TREES.

A large percentage of the injury to the wood of insect, fire, and lightning killed trees and those killed or dying from injuries by storms, disease, etc., can be prevented as follows:

(1) By the prompt utilization of such timber within a few weeks or months after it is dead or found to be past recovery.

(2) By removing the bark from the merchantable portions of the trunks within a few weeks after the trees are dead (the work to be done either before or after the trees are felled).

(3) By felling the trees and placing the unbarked logs in water.

(4) By the adoption of a system of forest management which will provide for the prompt utilization of all trees which die from any cause.

PREVENTION OF LOSS FROM INSECT INJURIES TO NATURAL AND ARTIFICIAL REPRODUCTION.

The successful control of the insects which destroy or prevent the normal development of natural reproduction is a far more difficult problem than that presented by other classes of insect injuries, but in this as in the others a great deal can be accomplished toward preventing the reduction of future supplies.

Much can be accomplished in nurseries and small plantations by the adoption of the ordinary methods of controlling farm and orchard insects, but in the natural forests reliance must be placed largely on systems of forest management which will bring about unfavorable conditions for the work of the more important enemies. (Hopkins, 1906*c*.)

Utilization of Immune and Resistant Varieties and Races of Trees.

Certain individuals representing varietal or racial forms of trees of a given species are sometimes found to be either immune or decidedly more resistant to the insects which are destructive or seriously injurious to the life or wood of other individuals or varieties of the same species. This fact suggests the importance of recognizing the well-known principle of improvement by selection. Thus, selecting seed or cuttings from such immune and resistant trees for artificial propagation, or taking great pains to leave such trees in commercial or selection cuttings for natural reproduction, will undoubtedly be an important step toward providing against damage and loss in the future. (Hopkins, 1906*b*, 1907*a*, 1907*c*, 1907*d*.)

PREVENTION OF INSECT INJURIES TO FOREST PRODUCTS.

The problem of artificial control and prevention of insect injuries to forest products offers less difficulties perhaps than that relating to many other branches of the general subject of forest-insect control. In most cases the principle of prevention is the only one to be considered, since the damage is done soon after the insects enter the wood, and therefore it can not be repaired by destroying the enemy.

Crude Products.

The proper degree of moisture found in the bark and wood of newly felled trees, saw logs, telegraph poles, posts, and like material, cut in the fall and winter and left on the ground or in close piles

during a few weeks or months in the spring and summer, or during the period when the particular species of injurious insects are flying, are some of the conditions most favorable to attack. The period of danger varies with the kind of timber and the time of the year it is felled. Those felled in late fall and winter will generally remain attractive to ambrosia beetles and adults of round and flat headed borers during March, April, and May. Those felled during the period between April and September may be attacked in a few days after they are felled, but the period of danger from a given species of insect may not extend over more than a few weeks. Thus certain kinds of trees felled during certain seasons are never attacked, while if they are felled at other times and seasons the conditions for attack may be most favorable when the insects are active, and then the wood will be thickly infested and ruined. The presence of bark is absolutely necessary for successful infestation by most of the wood-boring grubs, because the eggs and young stages must occupy the inner and outer portions before the latter can enter the wood. Some ambrosia beetles and timber worms will, however, attack barked logs, especially those in close piles or otherwise shaded or protected from rapid drying. A large percentage of the injury to this class of products can be prevented, as follows:

(1) Provide for as little delay as possible between the felling of the tree and its manufacture into rough products. This is especially necessary with trees felled from April to September in the region north of the Gulf States and from March to November in the latter, while the late fall and winter cuttings should all be worked up by March or April.

(2) Do not leave the round timbers in the woods or on the skidways during the danger period, or, if this is unavoidable, take every precaution to facilitate the rapid drying of the inner bark by keeping the logs off the ground, in the sun, or in loose piles, or else, if possible, the opposite extreme should be adopted and the logs kept in water.

(3) Remove the bark within a few days after the trees are felled, from poles, posts, and other material which will not be injured by checking or season cracks.

(4) Take advantage of the proper months or seasons in which to fell or girdle different kinds of trees to avoid danger.

Damage to products cut from saplings and left with the bark on can be prevented by transporting the material from the woods soon after it is cut, so that it will not be left in piles or bundles in or near the forest during the season of insect activity. Damage may also be prevented by care not to leave the material stored in one place for several months.

Pinhole damage to stave and shingle bolts cut during a warm season can be prevented by removing the bark from the timber as

soon as it is felled and by converting the bolts into the smallest practicable dimensions and piling them in such a manner as to facilitate rapid drying.

Damage to unseasoned handle and wagon stock in the rough can be prevented by taking special precautions to provide against the same favorable conditions for attack as mentioned in connection with round timbers. This is especially necessary with hickory and ash if cut during the winter and spring.

Damage to pulpwood and cordwood can be prevented to a great extent by placing the sticks of wood in triangular or crib piles immediately after they are cut from the trees, especially if the timber is cut during the danger period or must be held for a few months during the warm season. Peeling or splitting the wood, or both, before it is piled will also provide against damage from insects.

Manufactured Products.

UNSEASONED PRODUCTS.

Freshly sawed hardwood lumber placed in close piles during warm, damp weather in the period from July to September, inclusive, presents the most favorable conditions for injury by ambrosia beetles. In all cases it is the moist condition and retarded drying of the lumber which induces attack. Therefore any method which will provide for the rapid drying of the lumber before or after piling will tend to prevent loss. It is important, also, that heavy lumber should, as far as possible, be cut only in the winter and piled so that it will be well dried out before the middle of March.

The damage to lumber and square timber when the bark is left on the edges or sides can be prevented by removing the bark before or immediately after the lumber is sawed, or by sawing and piling the material during the winter, or if sawed at other times it should be piled so that rapid drying will be facilitated.

SEASONED PRODUCTS.

Unfinished seasoned products.—Injury by powder-post beetles to dry hardwood lumber and other material in stacks or storehouses can be prevented as follows:

(1) Have a general inspection of the material in the yards and storehouses at least once a year, preferably during November or February, for the purpose of (*a*) sorting out and destroying or otherwise disposing of any material that shows the slightest evidence of injury, as indicated by the presence of fine powdery boring dust, and (*b*) sorting out and destroying all old and useless sapwood material of any kind that will offer favorable breeding places for the insects.

(2) Prevent the introduction into the lumber yards or storehouses of any infested material, remembering that the insect may be thus distributed to or from all parts of the world.

(3) Adopt a system of classification of all dry or seasoned hardwood stock which will provide for (*a*) the separation of the pure heartwood material from the pure and part sapwood material; (*b*) classification of all kinds of wood most liable to attack, such as hickory, ash, oak; (*c*) the successive utilization or sale of the older material (remembering that material one year old or over is far more liable to injury); (*d*) providing against the accumulation of refuse material in which the insects could breed; and (*e*) treating the best material with linseed oil or kerosene to prevent attack.

Finished seasoned products.—Damage to finished handles, oars, spokes, rims, hubs, wheels, and other unpainted wagon, carriage, machinery, and implement stock in factories, wholesale and retail storehouses, and army and navy stores can be prevented by the adoption of the same general rules as those given under rough products. In addition, damage can be controlled and prevented in the following manner:

Sort out and (*a*) destroy all articles showing the slightest evidence of powder-post injury, or (*b*) treat with kerosene oil such infested and slightly injured articles as may be tested for required strength and found to be of sufficient value for retention, placing the same in quarantine for a sufficient time to determine whether the treatment is successful.

Damage by powder-post insects to many kinds of articles can be prevented and at the same time the material otherwise benefited by treating the sapwood with linseed oil or kerosene, either by immersing it in the oil or by applying the oil with a brush, the application to be made as soon as possible after the articles are finished from recently seasoned, uninjured stock.

Past and Present Conditions of Powder-Post Injury.

Up to 1906 there were a great many reports of extensive losses of valuable material from the ravages of powder-post beetles which were seriously affecting all industries involved in the manufacture, sale, and utilization of the classes of hardwood products affected by them. In response to these reports and accompanying appeals to the Department of Agriculture for information on causes and remedies, the problem was thoroughly investigated and specific advice and instructions relating to practical methods of control and prevention have been widely disseminated, both through publications of the Department and special correspondence.

Reports of present conditions from our principal correspondents, together with the less frequent requests for advice, indicate that

the disseminated information has been extensively utilized and that it has been worth many millions of dollars toward eliminating the losses and reducing the drain on the limited supply of the kinds of timber required to replenish the damaged and destroyed material.

The army and navy stores of handles, tent poles, wheelbarrows, oars, and many other hardwood articles have suffered severely from powder-post damage, involving an enormous loss, but the carrying out of the information already supplied has evidently contributed greatly toward the elimination of this source of loss to the Government.

Tan Bark.

Damage to hemlock and oak tan bark by the class of insects which in some cases has been so destructive to these products in the past can be easily prevented without cost, as follows:

(1) Utilize the bark within three years from the time it is taken from the trees.

(2) Prevent the accumulation in the yards and store-sheds of old bark and waste material in which the insects can breed.

These simple methods have been extensively adopted since their recommendation in correspondence and publications between about 1894 and 1904, and afford one of the most striking examples of the value of expert information on the peculiar habits of insects and of how millions of dollars can be saved without cost through a simple adjustment in methods of utilization.

Utilized Products.

Damage and loss from insect injuries to timber and other woodwork in structures of various kinds, to telephone and telegraph poles, posts, railroad ties, mine props, etc., can be prevented to a large extent through the adoption of the proper methods of management or of treating the material with preservatives before and after it is utilized.

Timbers and woodwork in structures.

Injuries to timbers and woodwork in dwellings, outbuildings, bridges, etc., by powder-post insects can be prevented as follows:

(1) Use nothing but heartwood for the concealed parts most liable to damage.

(2) If it is necessary to use all or part sapwood material, attack can be prevented by treating the sap portions with kerosene, coal tar, creosote, or linseed oil. Facilities for future treatment can be provided wherever the rough or finished woodwork is exposed, as in outbuildings, bridges, etc., if care is taken to expose the sapwood portions.

(3) If the untreated timbers and woodwork in old buildings show evidence of attack, the affected portions should be given a liberal application of kerosene.

Damage by white ants, or termites, can often be prevented in the following ways:

(1) By the use of nothing but sound wood for underpinning and foundation timbers and the removal of decaying timbers from old structures.

(2) By preventing moist conditions of the wood in any part of the structure and especially that in foundation timbers.

(3) By the treatment of timbers necessarily exposed to moist conditions with creosote, zinc chlorid, corrosive sublimate, etc.

(4) If the timbers become infested, further progress of insect damage can be prevented by removing the badly damaged parts and soaking the remainder with kerosene, fumigating with bisulphid of carbon, and by removing any adjacent decaying or other wood in which the insects have been breeding or may breed, such as logs, stumps, etc.

Log cabins and rustic work.—Damage by bark and wood boring insects to the unbarked logs and poles used in rustic cabins, summer houses, fences, etc., can be largely prevented by cutting the material in October and November and utilizing it at once, or by piling it off the ground or under cover in such a manner as to offer the best facilities for the rapid and thorough drying of the inner bark before the middle of March or the 1st of April following. If these necessary precautions are not taken, and there is evidence that insects are at work in the bark and wood, the damage can be checked by injecting bisulphid of carbon through natural or artificial openings in the affected bark, and immediately stopping these and other openings with putty or a similar substance.

Poles, posts, piles, ties, mine props, and similar products.—Insect damage to poles, posts, and similar products can be prevented to a greater or less extent by the preservative treatments which have been tested and recommended by the Forest Service for the prevention of decay. These should be applied before the material is utilized for the purposes intended, or, if it be attacked after it has been utilized, further damage can be checked to a certain extent by the use of the same substances.

It is often of prime importance to prevent injury from wood-boring insects, for the reason that such injuries contribute to more rapid decay. Therefore anything that will prevent insect injury, either before or after the utilization of such products, will contribute to the prevention of premature deterioration and decay.

UTILIZATION OF NATURAL ENEMIES AND FACTORS IN THE CONTROL OF INJURIOUS INSECTS.

Were it not for the natural checks and natural factors of control of some of the more destructive insect enemies of forest trees and forest products, artificial control would in many cases be impossible, and the depredations would evidently be far more continuous and complete. These natural factors in the control of the depredating insects consist of parasitic and predatory insects, diseases of insects, birds, adverse climatic conditions, etc. While one or more of these beneficial factors exert a continuous and powerful influence toward the prevention of a more extensive waste of forest resources, it has been repeatedly demonstrated that they can not be depended on to prevent widespread devastations or to otherwise work for the best interests of the private or public owner by protecting the best trees and the best tree species. The insects and birds which prey upon the depredating insects also have factors to contend against, consisting of insects, birds, diseases, and climatic conditions. Therefore under normal conditions the tendency is toward the preservation of a balance between the warring factors, but frequently the enemies of the trees get the ascendancy and take on the character of an invasion, which may continue for two or three or even ten years before the balance is again adjusted through the influence of the natural enemies or diminished food supply. Thus a vast amount of timber or of a given forest product may be destroyed before the factors of natural control can prevail.

It is evident that the most effective utilization of the factors of natural control will be through the alliance with them of the owner of the forest in the artificial reduction of the enemies of the trees rather than by efforts to make the natural enemies of the injurious insects his allies through artificial introduction or dissemination. The former is accomplished by the adoption of methods of combating the invaders which will reduce and weaken their forces below their power of prosecuting aggressive movements and attacks, or, as previously stated, to reduce their numbers to the point where they must occupy a defensive position against their natural enemies and be dependent for their supplies of food and breeding places upon that furnished through avoidable mismanagement of the forests and manufacturing operations. Thus the owner of the forest can contribute greatly toward the preservation of a balance which will be to his material benefit. On the other hand, he may in the future, as in the past, contribute greatly to the multiplication of the depredating insects and to greatly increased losses caused by them, through neglect or a disregard of available information on the fundamental prin-

ciples of insect control in the management of forests and manufacturing enterprises.

Beneficial Insects.

The beneficial insects comprise those which are internal or external parasites of the immature or mature stages of the injurious insects, and predators which feed on the young or adults of insects either before or after they make their attack on the trees or products. These two beneficial factors are doubtless far more effective in the long run than any other agencies of natural control. Yet they, in combination with all other factors, can not be always relied upon to render continued and efficient control. They can, however, be relied upon to respond to artificial assistance in reducing the numbers of the depredators.

Beneficial Diseases of Insects.

It is very evident that the parasitic fungi and bacteria which sometimes cause epidemics among injurious insects often exert a powerful influence toward the control of extensive outbreaks or invasions of insect enemies of forests. Indeed, it appears that the greatest service rendered by this class of natural enemies is in the frequent sudden appearance of an epidemic which kills off a destructive species of insect after the latter has increased to such numbers and extended its depredations over such vast areas as to be far beyond the control of man or his insect and bird allies. Numerous examples of this kind of natural control are found in the sudden ending of widespread depredations by various species of caterpillars and sawfly larvæ which defoliate deciduous and coniferous trees. As a rule, however, the beneficial effects of the diseases of insects prevail only after the injurious insects have increased to excessive numbers. Therefore this factor of insect control can not be depended upon to hold the insects in check or prevent outbreaks. The fact, however, that it operates on a class of insect enemies of the forest (defoliators) which at present can not be controlled by any known artificial methods renders the services of the diseases all the more valuable.

It is believed that with further knowledge of nature's method of propagating, perpetuating, and disseminating the diseases which cause epidemics among insects, they may be utilized more or less successfully through artificial propagation and dissemination to prevent threatened invasions of defoliating insects.

Beneficial Birds.

It is very evident that certain kinds of birds, such as woodpeckers, render valuable service toward the natural control of destructive bark and wood boring insects. They appear to render the greatest

service, however, where but few trees are being killed or injured, because their concentrated work on such trees may contribute toward the prevention of an abnormal increase of the insects. They also render some service as allies of the other beneficial factors which assist in artificial control. It is evident, however, that where many hundreds or thousands of trees are being killed the comparatively limited number of birds in any forest under the most favorable conditions could have little or no beneficial effect. Therefore, while the birds should be classed among the valuable friends of the forest, and should be protected, it is plain that they can not, even with the utmost protection, always be relied upon to protect the forest against destructive ravages of insects.

We must remember, in this connection, that there are complicated interrelations between birds, injurious insects, and beneficial insects which do not necessarily always operate to the benefit of the forest. In fact, it may sometimes be quite the reverse. Therefore, in order to derive the greatest benefit from the conflict between the birds, the insect enemies of the trees, and the insect friends of the trees, we must utilize our knowledge of the factors which are contributing toward the preservation of a balance, so that whenever the enemies of the forest threaten to get beyond natural control we may enter the field through artificial means and endeavor to force them back to their normal defensive position.

Beneficial Climatic Conditions.

The benefits to be derived from climatic conditions which are detrimental or destructive to insect enemies of the forest, while sometimes very great, are necessarily unreliable, and thus can not be depended upon to assist in artificial control. In fact, the very condition which may contribute to the destruction of one depredator may favor the multiplication of another.

Utilization of waste caused by insects.

When we come to consider the vast amount of standing timber in the forests of the country which has been injured or killed by insects, and will go to waste if it is not utilized within a limited period, we realize that there are great possibilities in its utilization as a means of preventing the reduction of future supplies of living healthy timber. It is all the more important that the insect-infested timber should be utilized, because in so doing we can contribute more perhaps than in any other way to the reduction of the insects to or below their normal numbers, and thus provide against serious injury in the future, as well as to the maintenance of control.

PRESENT CONDITIONS AND OPPORTUNITIES.

Unfortunately, the examples of management, or rather mismanagement, which are contributing to an extension or increase of waste are far in excess of those which under proper management are contributing to the reverse. This is due in a large part to the conditions that have prevailed in American forests in the past that have rendered it impracticable to adopt improved policies of forest management, but at present it is largely due to a lack of appreciation of the importance of the subject, and of the opportunities to prevent such losses, when it is not only practicable but possible to do so, and when it will, at the same time, yield large returns on the necessary additional expense. This is especially true in thousands of farmers' woodlots and private holdings in the States east of the Mississippi River, in which from 25 to 90 per cent of all of the serious injury of the past can be prevented in the future with little or no additional expense over that required for ordinary good forest management.

Forest Entomology as Applied to American Forests.

It is only within the past eleven years that any attempt has been made toward a systematic investigation of the insect enemies of the forest trees and forest products of the entire country. The state of knowledge of the subject previous to that time can be judged by the fact that a number of the most destructive enemies of forest trees are found to be new to science, and that nothing whatever was known of the habits and seasonal history of a large number of the more important known species which are common enemies of forest trees and forest products, while scarcely anything was known in regard to practical methods of controlling the principal enemies of the forest and its products, or of preventing losses from their ravages as applied to conditions in this country.

PRESENT KNOWLEDGE.

Within the past ten years forest-insect investigations have been conducted by the Bureau of Entomology of the Department of Agriculture in all of the principal forest regions of the United States, and have led to the following results:

Results of investigations.—Satisfactory progress has been made toward the attainment of some of the fundamental objects of the investigations, one of which has been the laying of a substantial foundation for forest entomology in this country on which future progress can be made along the lines of acquiring, disseminating, and applying information of immediate practical value in the protection of our forest resources.

Acquired and new information.—The principal insect enemies of the forests and forest products of North America have become

known, and the general character and extent of their depredations have been ascertained.

The more important facts in the life history, habits, and practical methods of control relating to some of the more destructive insects have been determined.

A mass of original data has been collected relating to forest insects in general, including not only those which are destructive or injurious, but also those which are beneficial or neutral in their relation to the forest, as represented by a collection of more than a million specimens of insects and their work.

As a direct result of the investigations of forest insects during the past six years, at a cost of less than $53,000, there has been accumulated a reserve fund of information now available through publications, correspondence, and field demonstrations which, if properly utilized for practical application, would evidently prevent from 10 to 30 per cent of the annual losses at a very small cost.

Disseminated information.—In addition to information disseminated in all sections of the country through correspondence, lectures, demonstrations, exhibitions, etc., the published information, based on results of investigations conducted by the West Virginia Agricultural Experiment Station and by the Bureau of Entomology of the U. S. Department of Agriculture during the past eighteen years, is represented by over 1,300 pages, 99 plates, and 340 figures. (See list of publications.)

NEEDS.

The work that has been done is only a beginning in the vast field of forest entomology. There is need of more systematic work (or so-called pure science) on the different stages of the thousands of species of injurious and beneficial insects involved. *This is absolutely necessary in order to have the further scientific basis of facts on which to build the structure of complex details necessary to success in practical application in its broadest sense.*

There is need of further detailed study of habits and seasonal history of the species of injurious and beneficial insects, as well as of the local and other conditions favorable and unfavorable for their multiplication and work.

Further information is desirable on the principal factors of natural control of injurious insects, in order that it may be better utilized to facilitate artificial control.

There is special need of more general information and public interest in the subject of losses from insect depredations on standing timber and timber products, and a better realization of the possibility and practicability of preventing losses.

Looking to this end, there is need of further demonstration and educational work along the lines which will bring the matter to the

attention of the man in the woods, sawmill, factory, or trade who is in direct touch with the local conditions and business methods.

There is a special need of more experts in forest entomology, and there will be an increasing demand for such experts in the future, to organize and take charge of insect-control policies in state forests, in public parks, in the more extensive private or commercial forests, and in extensive manufacturing enterprises, and to give instructions to students in forestry schools and forestry departments in state and other institutions of learning.

The need of trained and experienced experts in forest entomology for all of this class of work can not be too strongly urged. There is perhaps no branch of economic or applied science which requires more technical knowledge and practical experience as a basis for proper investigations and authentic instructions and advice than forest entomology, and there is perhaps no other feature in the science and practice of forestry in which advice and application based on insufficient knowledge is so dangerous.

There is quite a general recognition of the importance of guarding against contagious diseases, of the necessity of consulting a physician in cases of serious illness, and of relying on authorized pharmacists to fill the prescription, and then administering the prescribed treatment according to directions, but it is a notable fact that there are comparatively few persons who, even when deeply interested in preserving the health of the forest, have heretofore recognized the importance of guarding against insect epidemics or of consulting an expert forest entomologist in case of a threatened or existing outbreak. It has often happened that when such advice has been sought and received, the treatment was not administered according to the recommendations but changed to suit the ideas of some one entirely ignorant of the facts and principles upon which it was based. This has often resulted not only in failure to accomplish the desired end, but has contributed to an aggravation of the trouble and increased loss. The determination of the cause of specific troubles affecting the individuals of a given species of forest tree or an injury to a given type of product is just as complicated and requires the same elements of experience, training, and skill as that required for the determination of the cause of a given disease or the character of a given injury affecting man. It is just as important to know the cause or character of injury in the former as it is in the latter, in order to prescribe the specific treatment which will yield the desired results.

Therefore, in order to make the best progress toward preventing future waste of our forest resources from depredations by insects, every one interested in the subject, and especially those in authority in the public and private institutions of investigation and learning, should see to it that the instructions to students and the information

given out to the public is not only the best available but that it is limited to the range of expert knowledge of the subject possessed by the instructor or investigator.

Elementary and Technical Knowledge of Forest Entomology for the Forester.

While it may be desirable that every professional forester should have an expert knowledge of forest entomology, it is rarely possible, even under exceptionally favorable conditions, for him to acquire more than the necessary elementary knowledge, and even this has not been possible under the conditions which have necessarily prevailed in the forest schools, and in the practice of forestry, in this country. Little or no time has been available for acquiring the necessary information from subsequent study and practical experience. Therefore this feature in the education of the American forester has been practically neglected.

Present requirements of instruction.

As long as expert forest entomologists and authentic text-books based on American insects and conditions are not available for giving a complete course in technical and applied forest entomology the requirements of such a course should be limited to instruction in elementary entomology, and in elementary principles of applied forest entomology, which will give the necessary foundation for intelligent observations and utilization of available information as required in future practice.

CONCLUSION.

There is conclusive evidence that insects have been in the past, and are now, important factors in the waste and reduction of timber supplies, and will continue to be such in the future (pp. 57–58).

They attack perfectly healthy trees of all ages and kill them (p. 58).

They have at times killed a large percentage of the best timber over thousands of square miles of heavily forested lands (pp. 58–60).

They reduce the value of living timber and that of crude and finished products (pp. 60–66).

The accumulated evidence through many years of investigation and observation in the principal forest areas of the entire country by the writer and the field assistants in forest insect investigations furnishes the basis for the following summarized statements and estimates:

A large percentage of pine and spruce timber was killed by the southern pine beetle in 1890–1892 over an area of 75,000 square miles in West Virginia, Maryland, Pennsylvania, Virginia, and North Carolina (p. 58).

Billions of feet of matured spruce have been killed by the eastern spruce beetle during the past half century in the northeastern United States and southeastern Canada (p. 58).

A large percentage of the matured Engelmann spruce of the Rocky Mountains region has been killed by the Engelmann spruce beetle within the past fifty years (p. 59).

A large percentage of the pine timber of merchantable size in the Black Hills National Forest and other national and private forests of the central Rocky Mountains region has been killed during the past ten years by the Black Hills beetle (p. 59).

A large percentage of the best matured pine timber of the region north and west of Colorado and Utah has been killed within the past twenty years by the mountain pine beetle and the western pine beetle (p. 59).

A large percentage of the matured Douglas fir, or red fir, of the Rocky Mountains region has been killed by the Douglas fir beetle (p. 59).

The supply of hickory timber in the forests and woodlots of the States east of the Mississippi River has been greatly reduced by the ravages of the hickory barkbeetle (p. 60).

Practically all of the matured eastern larch has been killed over vast areas in the northeastern United States and southeastern Canada by the larch worm and eastern larch beetle (p. 60).

The wood of living timber has been rendered defective by wood-boring insects to such an extent as to reduce the value of a vast amount of standing timber from 50 to 75 per cent (p. 60).

Rapid deterioration of the wood of dying and dead trees has been caused by wood-boring insects, often amounting to from 25 to 100 per cent during the period in which it would otherwise be available for utilization (p. 62).

Crude manufactured and finished forest products have been damaged by insects to such an extent as to cause an estimated average annual loss of 10 per cent of its mill value (pp. 64–67).

Insects are the cause of greatly reducing our forest resources by killing the inaccessible timber; by reducing the quantity through injuries to the wood of living and dying timber; by preventing normal reproduction and development of future supplies, and through destroying forest products.

GENERAL ESTIMATES OF AMOUNT OF DAMAGE CAUSED BY FOREST INSECTS.

The results of extensive observations during the past ten years in the principal forested areas of all sections of the country, and during an additional eight years in West Virginia, indicate to the writer that the amount of standing timber killed by insects, together with

the standing living, dying, and dead timber reduced in quality and value by them in the forests of the country, to be found at any given time, has been not far from 10 per cent of the total stand of merchantable-sized timber (pp. 70–71).

Considering the forest in its broadest sense as a source of national wealth of a given value for all purposes, including direct utilization, protection of land from erosion, protection of headwater streams, protection of game, and as contributing to the real and aesthetic value of health and pleasure resorts, it is evident to the writer that the total damage caused by insects has been equivalent to an average additional 5 per cent of the value of the merchantable-sized timber of the entire country (p. 71).

Considering the problem of insect damage to standing timber and crude products on the basis of direct utilization of the forest resources, it is evident that the reduction in value below that of healthy timber or sound products at the time of utilization, including losses from handling defective material, has amounted to an equivalent of at least 10 per cent of the average annual mill value of the aggregate output of forest products of all kinds. This, of course, includes the killed and damaged merchantable-sized timber considered under the estimate relating to standing timber, given above. Since the killed and damaged standing timber is involved in any given annual output, this estimate on a basis of utilization represents more nearly a direct reduction in cash values (p. 71).

The writer estimates that the annual loss caused by insects injurious to finished and utilized products, including the consequent increased drain on the forest resources to replace that prematurely destroyed by insects, is equivalent to at least 3 per cent of the original or mill value.

HOW LOSSES CAN BE PREVENTED.

The results of extensive investigations and of practical applications during recent years have demonstrated that some of the most destructive insect enemies of American forests and of manufactured and utilized products can be controlled and serious damage prevented with little or no ultimate cost over that involved in good forest management and business methods.

It is evident that if the information now available through publications of the Department of Agriculture and through direct correspondence with its experts is properly utilized in the future it will result in the prevention of an equivalent of at least 30 per cent of the estimated annual waste of forest resources that has been caused by insects within recent years and thus contribute greatly to the conservation of the forest resources. This can be accomplished as follows:

(1) By the adoption or adjustment of certain requisite details in forest management, in lumbering and manufacturing operations, and in storing, transporting, and utilizing the products which, at the least expense, will bring about the necessary reduction of the injurious insect and unfavorable conditions for their future multiplication or destructive work.

(2) By the adoption of policies of control, based upon expert technical knowledge or advice relating to the species, habits, life history, and natural enemies of the insects involved, and methods for their control, supplemented by expert knowledge or advice on the principles of technical and applied forestry in the proper management, care, and utilization of the forest and its resources and still further supplemented by practical knowledge and experience relating to local conditions and facilities favorable and unfavorable for successful application according to a given method or policy of control.

(3) By reliance on technical advice furnished by recognized experts in forest entomology and forestry as a basis for success in practical application by the owner or forester.

(4) By utilization of so-called matured timber, and especially dense or pure stands of such timber, thus removing one of the favorable conditions for rapid deterioration through attacks by wood-boring insects or death through the attack of destructive bark-boring or defoliating insects.

(5) By the utilization of a knowledge of the principles of natural control as a means of contributing to the efficiency of artificial control.

(6) By prompt recognition of the first evidences of the work or destructive outbreaks of the principal insect depredators, by authentic identification of the species involved, and by prompt action in adopting the proper method or methods of control for the prevention of losses.

It should be remembered that as a rule it is useless to attempt the extermination of an insect enemy of the forest or its products. It is only necessary to reduce and weaken its forces at least 75 per cent, so that it can not continue an aggressive invasion, but must occupy a defensive position against its own enemies and become dependent upon favorable conditions resulting from avoidable negligence and mismanagement by the owners of the forests and the manufacturers of forest products.

While beneficial insects, beneficial birds, and beneficial diseases exert a continuous and powerful influence toward the prevention of a more extensive waste of forest resources, it has been repeatedly demonstrated that they can not be depended upon always to prevent widespread devastations or otherwise to work for the best interests of the private or public owner by protecting the best trees and the best tree species.

The best way to utilize the factors of natural control is to become their allies and assist in the reduction of the enemy, rather than to try to make them our allies through artificial introduction or dissemination.

A large percentage of the waste caused by insects can be prevented by the utilization of infested material, and at the same time, without additional expense, this will contribute greatly to the control of insects which cause such waste and also prevent injuries and depredations in the future.

Under past conditions the poor management or neglect of the average forest has contributed to the increase of depredations by insects.

Under present conditions of better management of local forests and of the more progressive manufacturing enterprises much is being accomplished toward the reduction of losses. In the average forest, and in the average business enterprise dealing with forest products, present conditions are little better than in the past. This is largely due to a lack of appreciation of the importance of the subject and failure to realize the opportunity and practicability of preventing a large percentage of the loss.

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